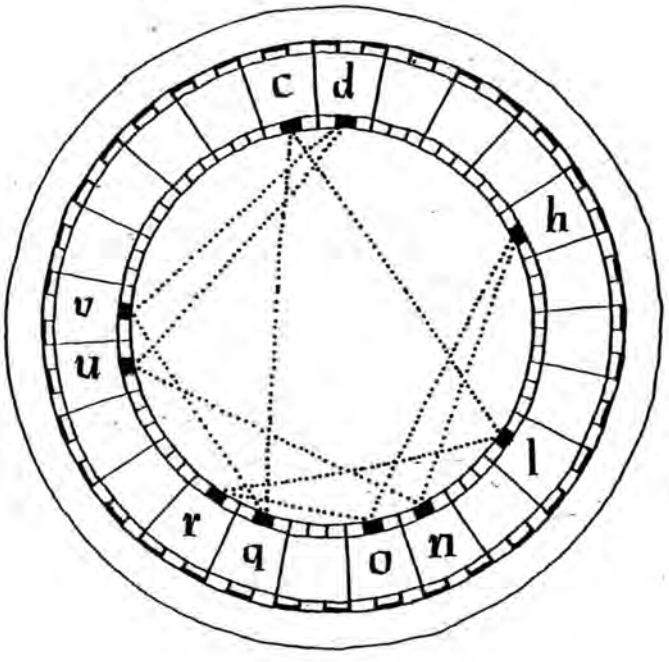
C is for chaos



by
j.m.rees
HATLEY WALKER

Introduction

In this graphic essay we aim to provide a mathematical, graphical, literary and etymologic context for what is known as chaos theory, also called non-linear dynamics or fractal geometry. Beware the faint of heart or the overtaxed ~~profes-~~ STUDENT ~~sor~~ who has too much to read and too little time in which to read it. The graphic essay, as a form, requires a different kind of reading. Conventional narrative is almost wholly absent. In its place are quotes and definitions, graphics and annotations. Reconstituting the story is our responsibility, *together*. It is a product of your willingness to play ~~with~~ us in the abyss. ~~Assuming~~ you are willing, ~~consider the graphics and text~~ as follows:

1) Live with the visualizations. Consider pinning them up on a wall. Regard the graphics at your leisure. Contemplate the quotes in relaxed moments.
2) Write your ideas and questions, your comments and criticisms on the manuscript. Make notes in any way that pleases you without regard to "spoiling" the pages. Free associate. You must hydrate the work. Water it an by your associative cognition. There is even *space* for you to add your own page.
3) Pass the manuscript along to another person who is curious about chaos. Encourage them to play.
4) At some point pass the palimpsest back to us so that we may enrich the next edition. Thank you.

Remember the essay is a background, the *context* of chaos, presented in an arbitrary alphabetical format. It is merely the beginning, a prelude to the song itself.

Graphic Conventions

> Refer to the visualization.

.c See also related discussion under this letter.

[Bibliographic citation opposite ">" for visualization otherwise in text.

Readers recommendations:

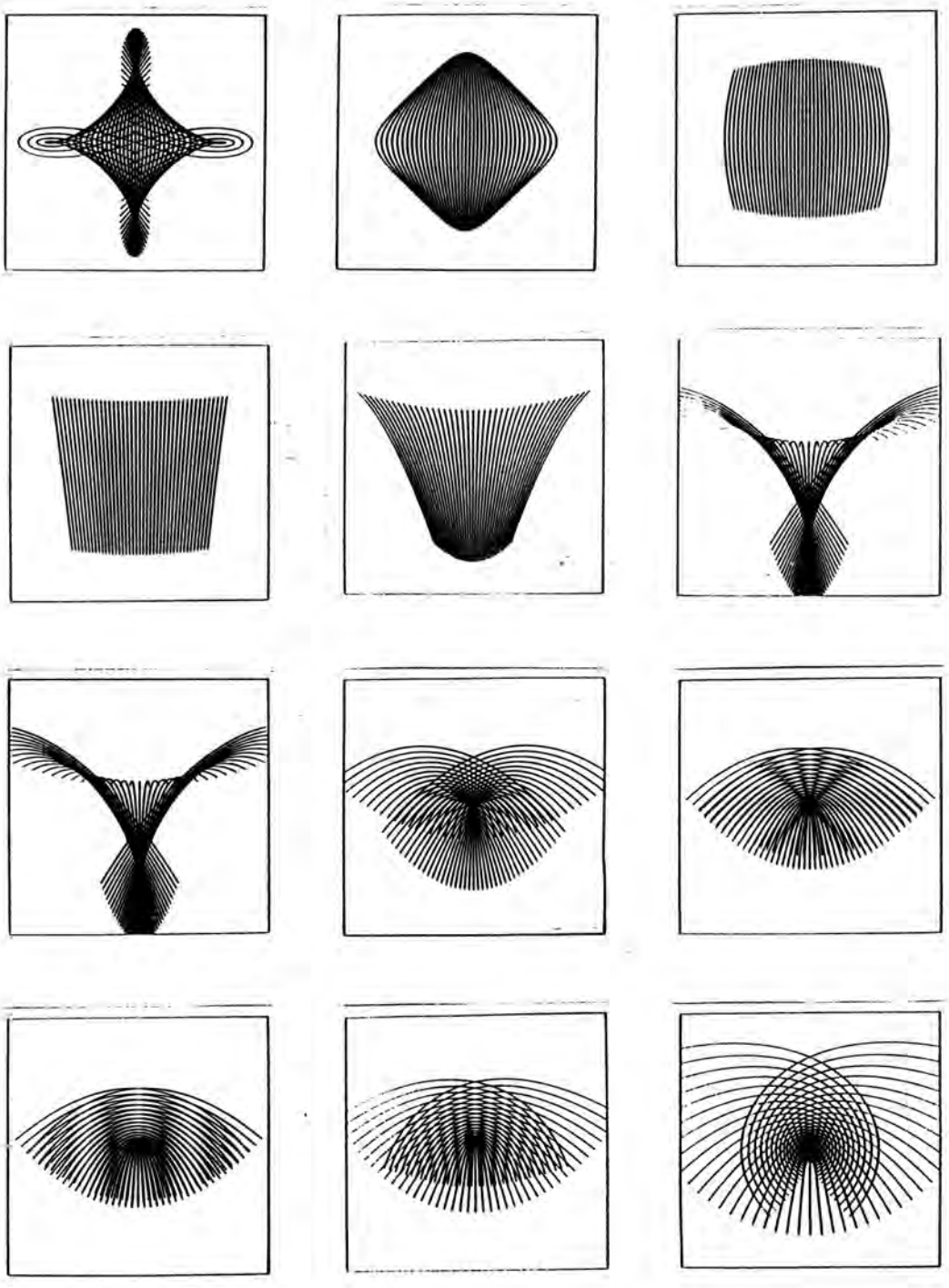
- *word* An alternate word, you recommend, to establish the context of chaos.

+ *word* Words contextualized and defined under the existing heading.

Readers marks:

Z

ZEEMAN



Z is for Zeeman

Zeeman and Thom are leading proponents of catastrophe theory, a mathematical technique for modeling discontinuous events. The mathematical roots of chaos theory are in catastrophe theory, in other words....

Catastrophe beget chaos.

> [Woodcock 1974

Graphs of catastrophic events are plotted in order to experimentally verify Thom's mathematical definition of symmetry. Two different equations are graphed evolving through six different states.

.c

ca-tas'tro-phe (-trō-fē), *n.* [L. *catastropha*, Gr. καταστροφή, fr. καταστρέφειν to turn up and down, to overturn; κατά down + στρέφειν to turn.] **1.** An event producing a subversion of the order or system of things; a final event, usually of a calamitous or disastrous nature; hence, sudden calamity; great misfortune.

The strange *catastrophe* of affairs now at London. *Bp. Burnet.*

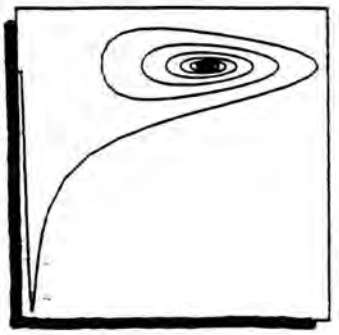
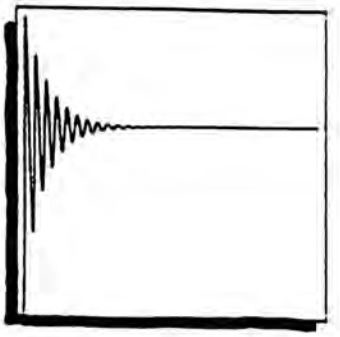
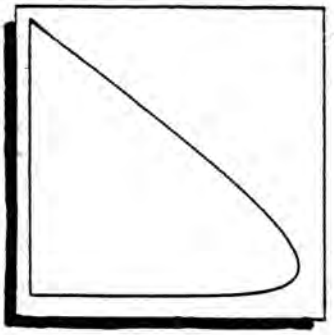
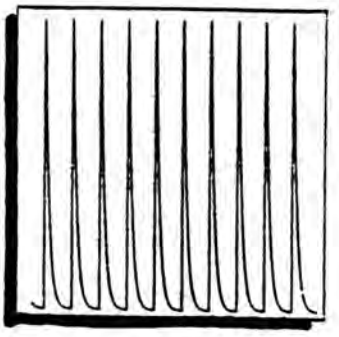
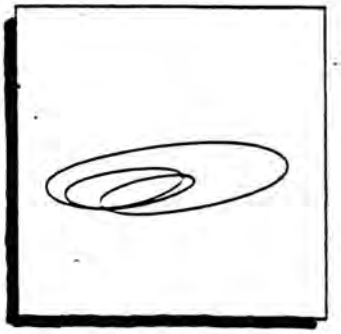
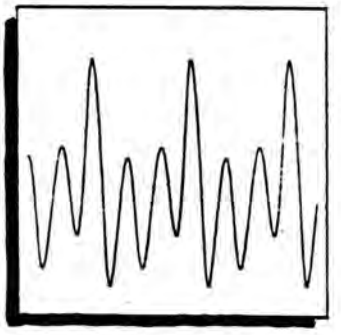
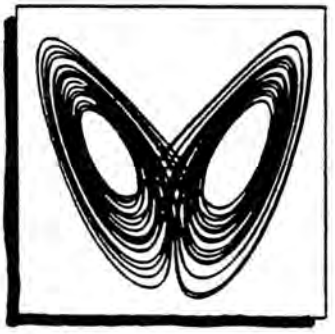
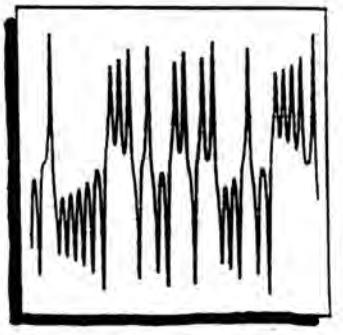
2. The final event in a romance, drama, etc.; dénouement, as a death in a tragedy, or a marriage in a comedy.

3. *Geol.* A violent and widely extended change in the surface of the earth. See CATASTROPHISM.

Syn. — See DISASTER.

a

ATTRACTOR

	Phase Space Portrait	Spectral Portrait
Spiral to a point attractor (EQUILIBRIUM)		
Period II		
Period III		
Chaotic State (STRANGE ATTRACTOR)		

also: Harmonic Analysis & Time Series Analysis

a is for attractor.

The world of events can be described dynamically by a picture changing in time and thrown onto the background of the three-dimensional space. But it can also be described by a static picture thrown onto the background of a four-dimensional time-space continuum. From the point of view of classical physics the two pictures, the dynamic and the static, are equivalent. But from the point of view of the relativity theory the static picture is the more convenient and more objective.

[Infeld 1952: 208

>

[Gleick 1987

According to Infeld four dimensional space may be represented as a three dimensional system evolving in time or as a static picture in four dimensional spacetime. By analogy, according to the representational conventions of dynamical systems, spectral analysis is a one-dimensional system (a line) evolving in time. The phase space portrait is a static two dimensional representation of the state of the system. In other words strange attractors are static patterns made from collapsed instants of dynamical systems.

.d .t

at-tract′ (ă-trăkt′), *v. t.*; AT-TRACT′ED; AT-TRACT′ING. [L. *attractus*, p. p. of *attrahere*; *ad* + *trahere* to draw. See TRACE, *v. t.*] **1.** To draw or draw in, as by suction; specif., to inhale. *Obs.*

2. To draw to, or cause to tend to; esp., to cause to approach, adhere, or combine; or to cause to resist divulsion, separation, or decomposition; to act upon by attraction.

> All bodies and all parts of bodies mutually *attract* themselves and one another. *Derham.*

3. To draw by influence of a moral or emotional kind; to engage or fix, as the mind, attention, etc.; to invite or allure; as, to *attract* admirers.

> *Attracted* by thy beauty still to gaze. *Milton.*

Syn.—Draw, allure, invite, entice, influence.

attracted-disk electrometer, an electrometer in which the attraction is determined between a metal plate and a disk suspended just above and parallel to it. Cf. BALANCE ELECTROMETER.

at-trac′tion (ă-trăk′shŭn), *n.* [L. *attractio*: cf. F. *attraction*.] **1.** Act, process, property, or power of attracting.

2. *Physics.* A force acting mutually between particles of matter tending to draw them together and resisting their separation. See FORCE. Of the various forms of attraction, *gravitation* acts universally and varies with the inverse square of the intervening distance; *magnetic* and *electrical attraction* are of limited sensible range and polar in action; *chemical affinity*, and *cohesion* and *adhesion* (of which *capillarity* is a form), act only at insensible distances.

3. That which attracts; an attractive object or feature.

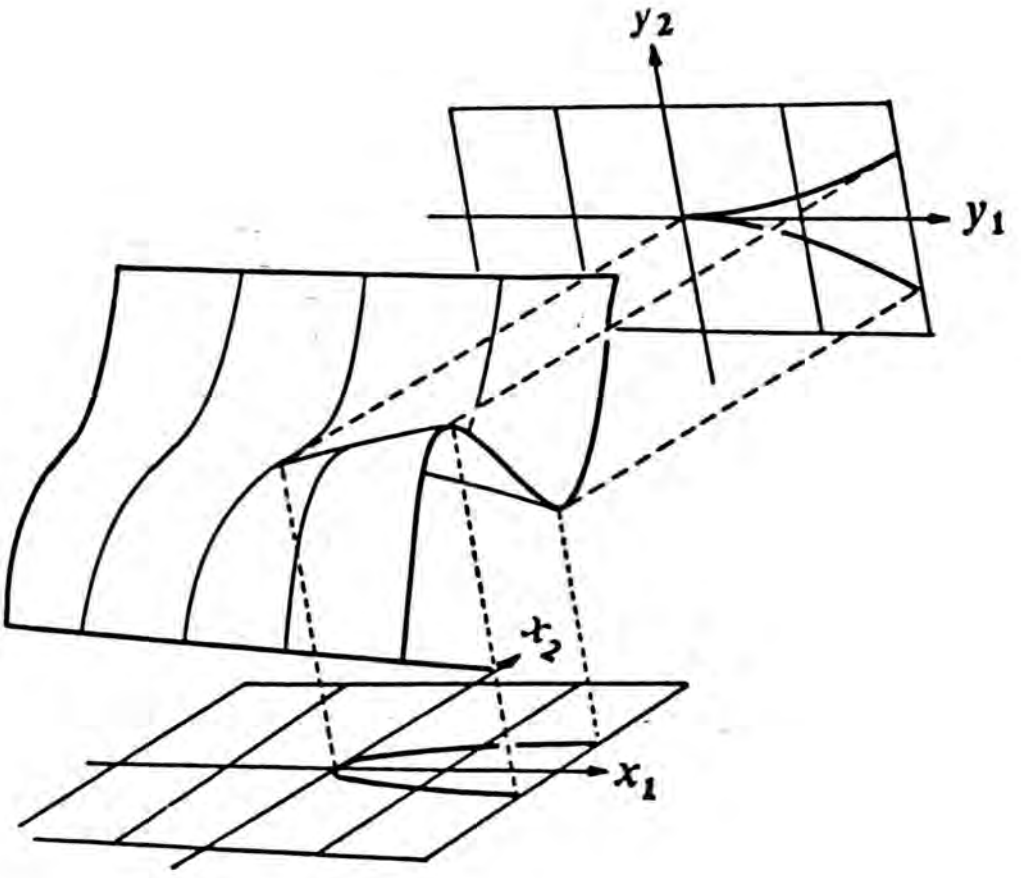
Syn.—Allurement, enticement, charm.

attraction of composition, *Chem.*, chemical affinity. *Obs.*

attraction sphere. **1.** *Zoöl.* **a** The central mass of the aster in mitotic cell division; centrosphere. **b** Less often, the mass of archoplasm left by the aster in the resting cell. **2.** *Bot.* A small body situated on or near the nucleus in the cells of some of the lower plants, consisting of two centrospheres containing centrosomes. It exercises an important function in mitosis.

b

BIFURCATION


y_2
y_1
x_2
x_1

b is for bifurcation

He saw it all painted across the
screen-pitchfork bifurcations,
stable lines breaking into two,
then four, then eight; the
appearance of chaos itself; and
within the chaos, the astonishing
geometric regularity.

[Gleick1987: 305

>

[Callahan 1974

Imagine bifurcation as an event
in three dimensional space. We
propose that it looks like a
wrinkled plane. The shape of the
event may be viewed as projected
in various coordinate systems.
Different views reveal different
properties. For instance it is
possible to differentiate the
graph of the event in the X plane,
it is not in Y. Our geometries
allow us multiple representations
of the same phenomena.

.h .j .t .g

bi-fur′cate (bī-fûr′kât) } *a.* [*bi-* + *furcate.*]
bi-fur′cat-ed (-kāt-ĕd ; bī′fŭr-kāt/ĕd) } Two-pronged.

bi-fur′cate (bī-fûr′kāt ; bī′fŭr-kāt), *v. i.* To divide into two branches.

bi′fur-ca′tion (bī′fŭr-kā′shŭn), *n.* A forking, or division into two branches.

C

CHAOS

C is for chaos

Chaos is a time evolution with sensitive dependence on initial condition.

[Reulle 1991: 67

A very small cause, which escapes us, determines a considerable effect which we can not ignore, and we then say that this effect is due to chance. Poincare in

[Reulle 1991: 48

>

[Schwenk 1976

Chaos theory grew out of our attempts to understand and model systems in flux: Climate, water, atmosphere etc. Modeling is only possible with the number crunching capacity of computers. A new geometry is emerging. The theory of this geometry is called chaos.
Gleek it graphically

.b .l .q .z

cha'os (kā'ŏs), *n.* [L. *chaos* chaos (in senses 1 & 2), Gr. χάος, fr. the root of χαίνειν to yawn, to gape, to open widely. Cf. CHASM.] **1.** An empty, immeasurable space; a yawning chasm, gulf, or abyss. *Obs.*

> Between us and you there is fixed a great *chaos*.
> *Luke* xvi. 26 (*Rhemish trans.*).

2. The void and formless infinite; the confused, unorganized state of primordial matter before the creation of distinct and orderly forms; — sometimes personified [*cap.*], esp. by the Greeks, as the most ancient of the gods. Cf. ABYSS, 1.

3. Any confused or disordered collection or state of things; a confused mixture; complete confusion or disorder.

> One rose out of the *chaos* of the slain. *Shelley.*

4. An undigested or shapeless lump or mass. *Obs. Shak.*

5. *Philos.* A state of things in which chance is supreme; nature conceived as subject to no law, or as not necessarily uniform.

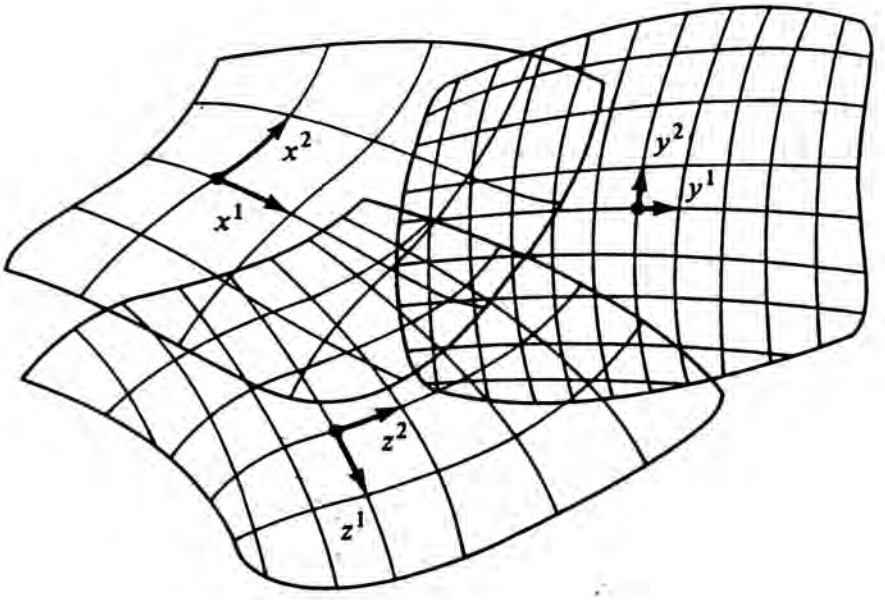
Syn. — See CONFUSION.

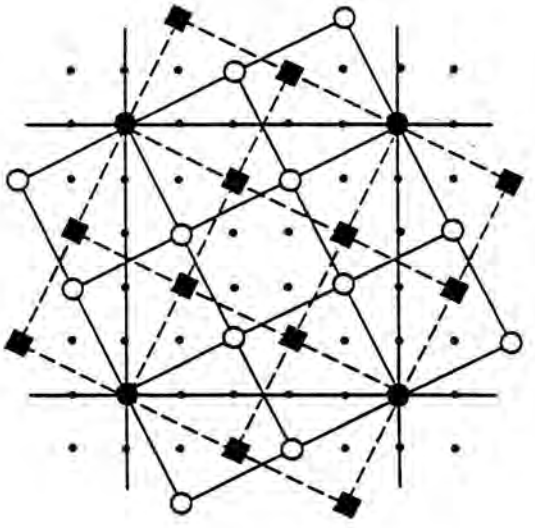
cha-ot'ic (kā-ŏt'ĭk), *a.* **1.** Of or pertaining to chaos; in the state of chaos.

2. Resembling chaos; completely confused.

d

DIMENSION


x^2
x^1
y^2
y^1
z^2
z^1



d is for dimension

The eye of man hath not heard, the ear of man hath not seen, man's hand is not able to taste, his tongue to conceive, nor his heart to report, what my dream was.

[MND IV. i. 214-7

In projective geometry there is no absolute space, no concept of volume. A sphere is not the collection of all points that are bounded by a spherical membrane. The sphere is a surface, the membrane only. In physics this is called a field.

>

(above) Three contiguous surfaces of local Euclidian geometry and unknown global geometry. [Penrose 1978

(below) Three congruent surfaces in a space that is globally Euclidian

[Toffoli 1987

.e .g .l

di-men'sion (dĭ-mĕn'shŭn), *n.* [L. *dimensio*, fr. *dimensus*, p. p. of *dimetiri* to measure out; *di-* = *dis-* + *metiri* to measure: cf. F. *dimension*. See MEASURE.] **1.** Act of measuring. *Obs.*

2. Measure in a single line, as length, breadth, height, thickness, or circumference; — usually *pl.*, measure in length and breadth, or in length, breadth, and thickness; extent; size; as, the *dimensions* of a room, of a ship, of a farm.

3. *pl.* Extent; reach; scope; importance; as, a project of large *dimensions*.

4. *pl.* Measurable parts; parts that give proportion or shape; as, the *dimensions* of a man.

5. *Math.* The degree of manifoldness of a magnitude or aggregate as fixed by the number of determinations or conditions necessary and sufficient to distinguish any one of its elements from all others. Thus time or a line has only one dimension (in instants or points); a surface has two dimensions, as the surface of a sphere, to fix a point on which we need to know its latitude and longitude; space about us has three dimensions, since to fix one of its points, as a star, we must know its right ascension and declination and distance. But space conceived as composed not of points but of lines is four-dimensional, since four determinations are necessary to fix a line in space. So a plane viewed as made up of circles has three dimensions, since two determinations fix the center and one more the radius of a circle. In general, a magnitude is of varying dimensions according to the elements of which it is made up. The simplest and most commonly used element is the *point*. Space of four dimensions, in the ordinary sense, is a point space, consisting of a fourfold infinity of points, and so for higher spaces of *n* dimensions.

6. *Alg.* A literal factor, as numbered in characterizing a term. The term *dimensions* forms with the cardinal numbers a phrase equivalent to *degree* with the ordinal; thus, a^2b^2c is a term of five *dimensions*, or of the fifth degree.

7. *pl. Mech.* The manifoldness or degree with which the fundamental units of time, length, and mass enter into the units of other physical quantities. Thus, since the unit of velocity varies directly as the unit of length and inversely as the unit of time, the *dimensions* of velocity are said to be *length* ÷ *time*; the *dimensions* of work are *mass* × (*length*)^2 ÷ (*time*)^2; the *dimensions* of density are *mass* ÷ (*length*)^3, or one in mass and minus three in length (written as a *dimensional equation* $D = ML^{-3}$, D representing density, M mass, and L length).

dimensions of an array, *Math.*, the numbers of its rows and columns.

di-men'sion, *v. t.;* DI-MEN'SIONED (-shŭnd); DI-MEN'SION-ING.

1. a To measure, as building material. **b** To cut, plane, or rub to required dimensions, as building material.

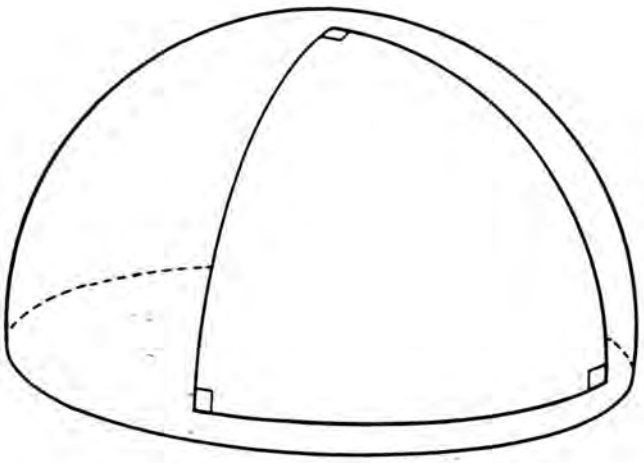
2. To figure with dimensions, as a drawing of architecture or machinery.

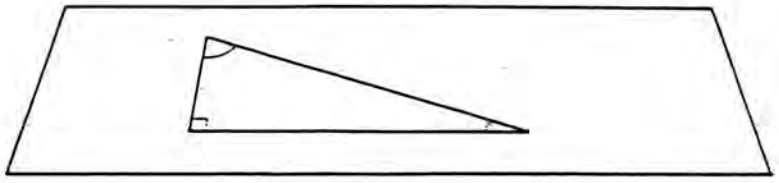
di-men'sion-al (-ăl), *a.* Of or pertaining to dimension; having dimensions (usually specified in number), esp. of length; as, one-*dimensional*, two-*dimensional*, etc. See DIMENSION, *n.* — **dimensional ratio,** in magnetism, the ratio of the longest to the shortest diameter of an elongated ellipsoid of revolution.

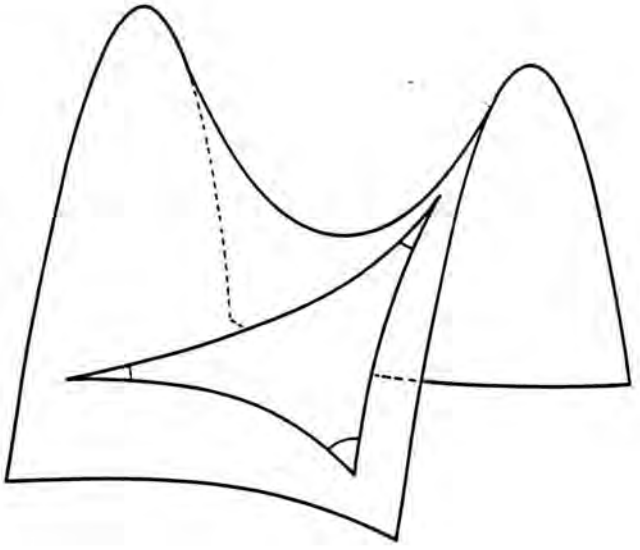
— **di-men'sion-al'i-ty** (dĭ-mĕn'shŭn-ăl'ĭ-tĭ), *n.*

e

EUCLIDIAN







e is for Euclidian

Riemann proved that Euclidean symmetry operations are a special rather than the general case of geometry.

Riemann assumes that finite unbounded spaces of constant positive curvature are possible, corresponding to the unbounded but finite two-dimensional surfaces of the sphere, while what we commonly take to be infinite space would correspond to the unlimited plane of curvature zero, and similarly a third species of space would correspond to surfaces of negative curvature.

[Mach 1894:107

>

[Weeks 1985

The sum of the angles of a triangle in spaces of different constant curvature:

curvature	sum of the angles
+1	<180
0	=180
-1	>180

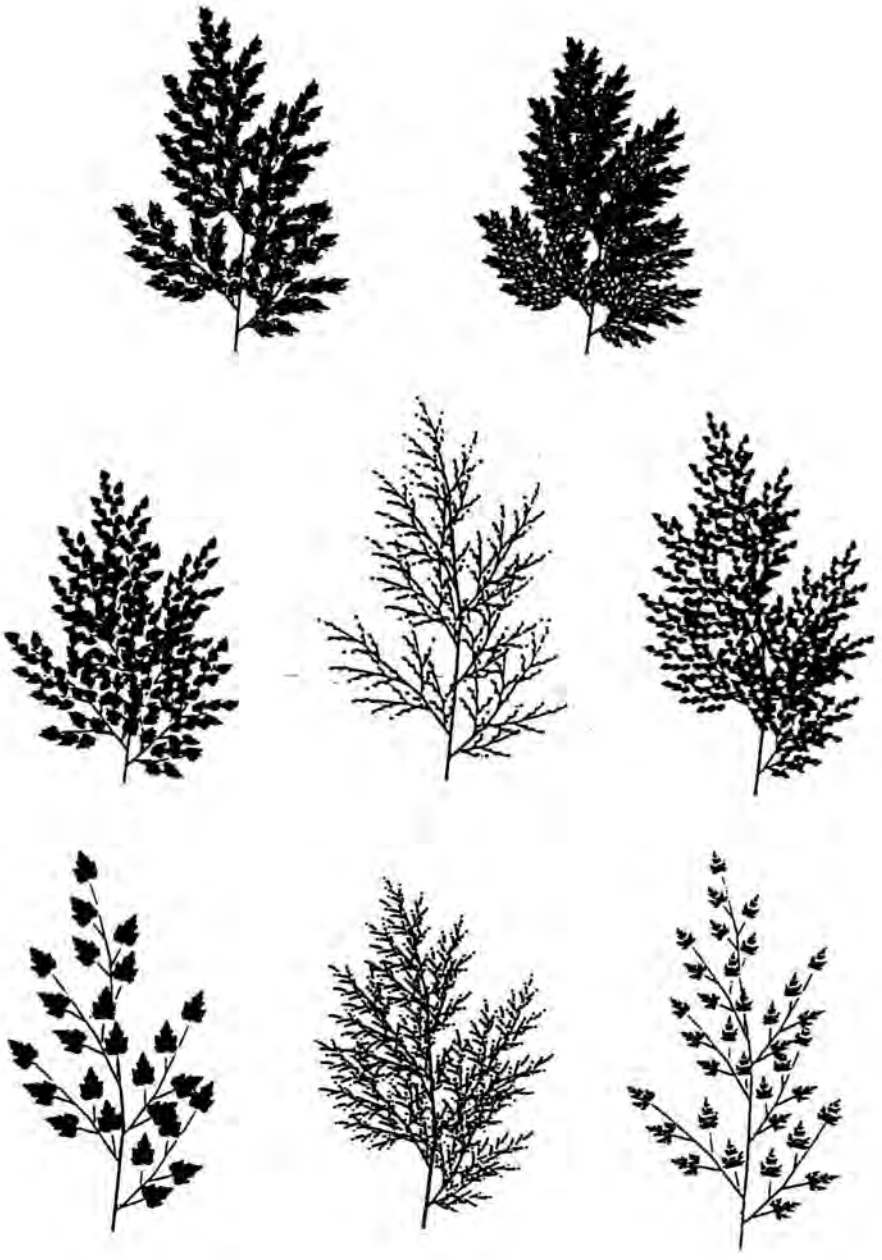
.s :k

Eu'clid (ū'klĭd), *n.* [L. *Euclides*, Gr. Εὐκλείδης.] A Greek geometer of about 300 B. C.; also, his treatise on geometry, and hence, the principles of geometry, in general.

Eu-clid'e-an (ū-klĭd'ē-ăn; ū'klĭ-dē'ăn; 277), **Eu-clid'i-an** (ū-klĭd'ĭ-ăn), *a.* Of or pert. to Euclid; specif., *Geom.*, adopting Euclid's assumptions with respect to space; pert. to geometry as developed in Euclid's "Elements."

Euclidean construction, a geometric construction by the use of ruler and compasses. — **E. geometry**, *Math.*, ordinary geometry; the geometry of Euclidean space. — **E. space**, *Geom.*, the kind of space to which the axioms and definitions of Euclid, relative to straight lines and parallel lines, apply; — called also *flat space*, and *homaloidal space*. In Euclidean space the Riemannian *measure of curvature*, $\frac{1}{k^2}$, is 0; hence: (1) The straight line is infinite. (2) The sum of the three angles of a plane triangle is a straight angle. Rigid bodies may be translated and rotated every way.

FRACTAL



is for fractal

The fractal folds of narrative, its self-similar and frequently tangled layers of plot, subplot, monologue, and dialogue, allow a culture to store tremendous amounts of information in a stable form while simultaneously freeing that information to vary according to historical [and pressumeably artistic] influences.

[Argyros 1991: 319

But how should a fractal set be defined? The tentative definition... is a set whose Hausdorff-Besicovitch Dimension strictly exceeds its topological dimension. But I like this definition less and less...I feel...that the notion of fractal is more basic than any particular notion of dimension...A reason for not defining fractals resides in the broadly held feeling that the key factor to a set's being fractal is invariance under some class of transformations, but no one has proven this invariance satisfactorily.

[Mandelbrot 1983: 1675

>

[Peterson 1987

frac′tion (frăk′shŭn), *n.* [F. *fraction*, L. *fractio* a breaking, fr. *frangere*, *fractum*, to break. See BREAK.] **1.** A breaking; specif., *Eccl.*, the breaking of the bread by the priest during the consecration in the Eucharist.

2. A part or piece broken off; hence, a separate portion; a fragment; a scrap.

> Some niggard *fractions* of an hour. *Tennyson.*

3. A fracture; a rupture; breach; break. *Obs.*

4. In technical senses: **a** *Arith.* One or more aliquot parts of a unit or integer; an expression for a definite portion of a unit or magnitude, or for any indicated unexecuted division. **b** *Alg.* The indicated quotient of one algebraic expression divided by another. **c** *Symbolic Logic.* A representation of a relation of logical classes in a fractional notation analogous to the algebraic. **d** *Chem.* One of several separately collected portions of a distillate, precipitate, or the like. See FRACTIONAL DISTILLATION.

compound fraction, *Arith.*, a fraction of a fraction; an indicated multiplication of two or more fractions, as $\frac{3}{4} \times \frac{4}{5}$ or $\frac{3}{4}$ of $\frac{4}{5}$.

frac′tion (frăk′shŭn), *v. t.*; FRAC′TIONED (-shŭnd); FRAC′TION-ING. To separate into fractions; to fractionate.

frac′tion-al (-ăl), *a.* **1.** Of or pertaining to fractions or a fraction; of the nature of, or constituting, a fraction; as, *fractional* numbers.

2. Relatively small; inconsiderable; insignificant; as, a *fractional* part of the population.

3. *Stock Exchanges.* Being, or relating to, a number or amount less than the unit of dealing, which for shares is one hundred, and for grain 5,000 bushels; odd. *Cant.*

fractional currency, small coin, or paper notes, in circulation, of less value than the monetary unit. Cf. DIVISIONAL COINS. — **f. distillation**, a method of gradually separating the constituents of a mixture, as of water and alcohol, by subjecting it to distillation, collecting the distillate in several portions, or fractions, as the temperature rises, and repeating the process with these, uniting from time to time fractions which are practically identical. **Fractional crystallization** and **fractional precipitation** are processes which are based on the same principle of separating partial products which differ in properties. — **f. function.** = MEROMORPHIC FUNCTION. — **f. unit**, the unit of a fraction; the reciprocal of the denominator; thus, $\frac{1}{4}$ is the *fractional unit* of the fraction $\frac{3}{4}$.

frac′ta-bling (-blĭng) [*fract-* being fr. L. *fractus* broken. See FRACTED, TABLE.] *Arch.* The coping of the sloping or curved sides of a gable wall where it rises above the roof. *Obs.*

Chevron Fracted.

fract′ed (frăk′tĕd), *p. a.* [L. *fractus*, p. p. of *frangere* to break.] **1.** Broken; violated; fractional. *Obs.*

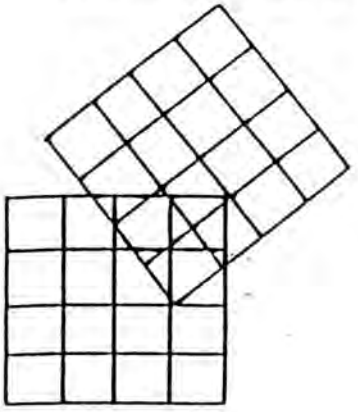
2. *Her.* Having a part displaced, as if broken; — said of an ordinary.

g

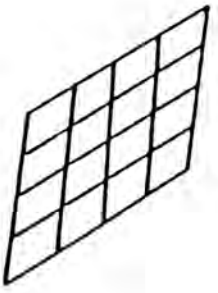
Geometry

GEOMETRIES

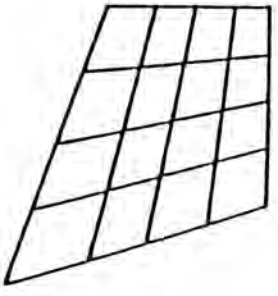
EUCLIDEAN



AFFINE

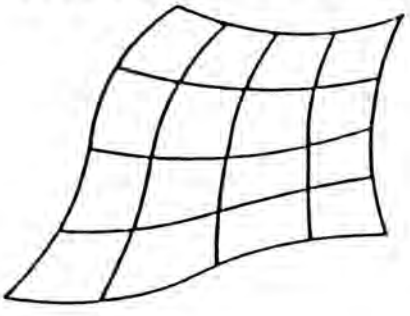


PROJECTIVE

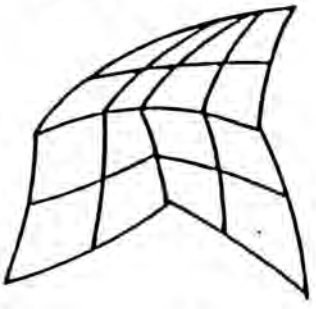


INVERSIVE

DIFFERENTIAL



TOPOLOGY



g is for geometry

Geometry is to space what music is to time. Francsis Warrain in [Ghyka 1977: 52

The genesis of mathematical creation is a problem which should intensely interest the psychologist. It is the activity in which the human mind seems to take least from the outside world, in which it acts or seems to act only of itself and on itself, so that in studying the procedure of geometric thought we may hope to reach what is most essential in man's mind. Poincare in [Ghiselin 1952: 33

> [Lord & Wilson 1986

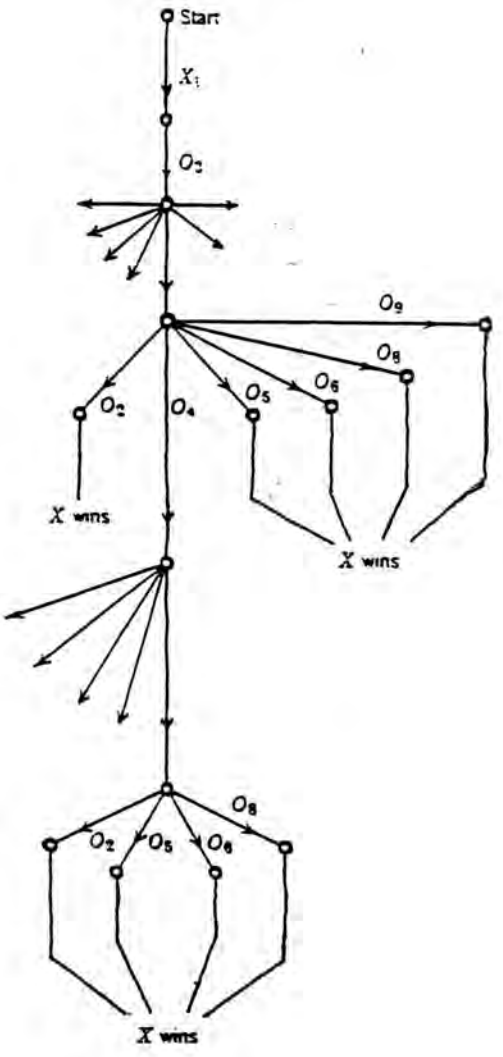
Felex Klein proposed the unification of all existing geometries into a single Geometry by operationalizing the concept of area.

.d .e .u

ge-om'e-try (jē-ŏm'ē-trĭ), *n.*; *pl.* -TRIES (-trĭz). [F. *géométrie*, L. *geometria*, fr. Gr. γεωμετρία, fr. γεωμετρεῖν to measure land; γαῖα, γῆ, the earth + μετρεῖν to measure. So called because one of its earliest and most important applications was to the measurement of the earth's surface. See GEOMETER.] **1.** That branch of mathematics which investigates the relations, properties, and measurement of solids, surfaces, lines, and angles; the science that treats of the properties and relations of spatial magnitudes; the theory of space and of figures in space; as at present conceived, the doctrine of series of two or more dimensions.
2. A treatise on this science.
geometry of forces, *Math.*, the doctrine of complexes and congruences of forces (represented by vectors).—**g. of position**, *Math.*, the study of the change in position of a locus as determined by the change in its equation (*Carnot*); also, modern projective geometry, as not dealing with metrical properties.—**g. of the compasses**, *Math.*, a geometry that does not admit the straight edge in drawing, but allows only constructions and determinations by means of links rotating about pivots; the doctrine of linkages. See STRAIGHT-LINE MOTION.—**g. on an algebraic curve** *or* **surface**, the theory of only those properties of a curve or surface that belong to all curves or surfaces related in a birational manner to the fundamental curve or surface.

h

HIERARCHY


Start
X_1
O_2
O_9
O_8
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O_4
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O_6
X wins
X wins
O_8
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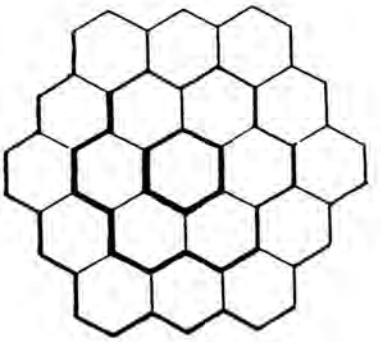
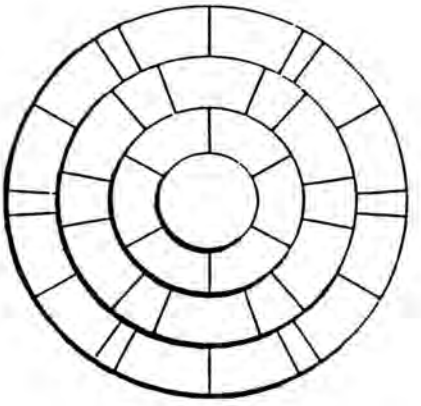
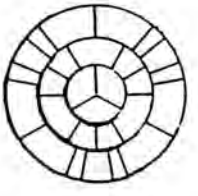
O_6
X wins







h is for hierarchy

But beauty, to us, connotes something more than sheer orderliness. It specifies a particular kind of orderliness. It postulates order compatible with uniqueness. This may sound like a paradox. [but] The paradox resolves itself if one considers the true hierarchical structure of nature, ... for [nature] admits of a measure of invariability, stability, and durability in a higher level system, notwithstanding the variability and changing constellation of its more elementary components.

[Weiss 1960: 179

>

Different ways to diagram hierarchical systems in game theory (left) and in inorganic chemistry. [Wells 1977

.o .c

hi′er-arch′y (-är′kĭ), *n.*; *pl.* -ARCHIES (-kĭz). [Gr. ἱεραρχία: cf. F. *hiérarchie.*] **1.** A rank or order of holy beings, primarily of angels.

> Standards and gonfalons . . . for distinction serve
> Of *hierarchies*, of orders, and degrees. *Milton.*

2. Dominion or authority in sacred things.

3. A body of officials disposed organically in ranks and orders each subordinate to the one above it; a body of ecclesiastical rulers.

4. A form of government administered in the church by patriarchs, metropolitans, archbishops, bishops, and, in an inferior degree, by priests. *Shipley.*

5. A series divided or classified in ranks or orders; esp., a series of classifying terms in natural science or logic.

hi′er-at′ic (hī′ĕr-ăt′ĭk), *a.* [L. *hieraticus*, Gr. ἱερατικός; akin to ἱερός sacred: cf. F. *hiératique.*] Consecrated to sacred uses; sacerdotal; pertaining to, or originated by, priests. Specif.: *Archæol.* Designating a style of ancient Egyptian writing called "hieratic" by the Greeks. It was an abridged form of hieroglyphic writing which assumed a cursive character, and was used for all literature, both secular and religious, until the demotic became prevalent, when hieratic was reserved for religious writings.

hi′er-at′i-co- (hī′ĕr-ăt′ĭ-kŏ-). Combining form from Greek ἱερατικός, *hieratic.*

hi′er-o- (hī′ĕr-ŏ-). Combining form fr. Greek ἱερός, *sacred.*

hi′er-oc′ra-cy (-ŏk′rȧ-sĭ), *n.*; *pl.* -CIES (-sĭz). [*hiero-* + *-cracy.*] Government by ecclesiastics; a hierarchy. — **hi′er-o-crat′ic** (-ō-krăt′ĭk), **hi′er-o-crat′i-cal** (-ĭ-kăl), *a.*

hi′er-arch (hī′ĕr-ärk), *n.* [LL. *hierarcha*, Gr. ἱεράρχης; ἱερός sacred (akin to Skr. *ishiras* vigorous, fresh, blooming) + ἀρχός leader, ruler, fr. ἄρχειν to lead, rule.] One who has high and controlling authority in sacred things; the chief of a sacred order; as, princely *hierarchs.*

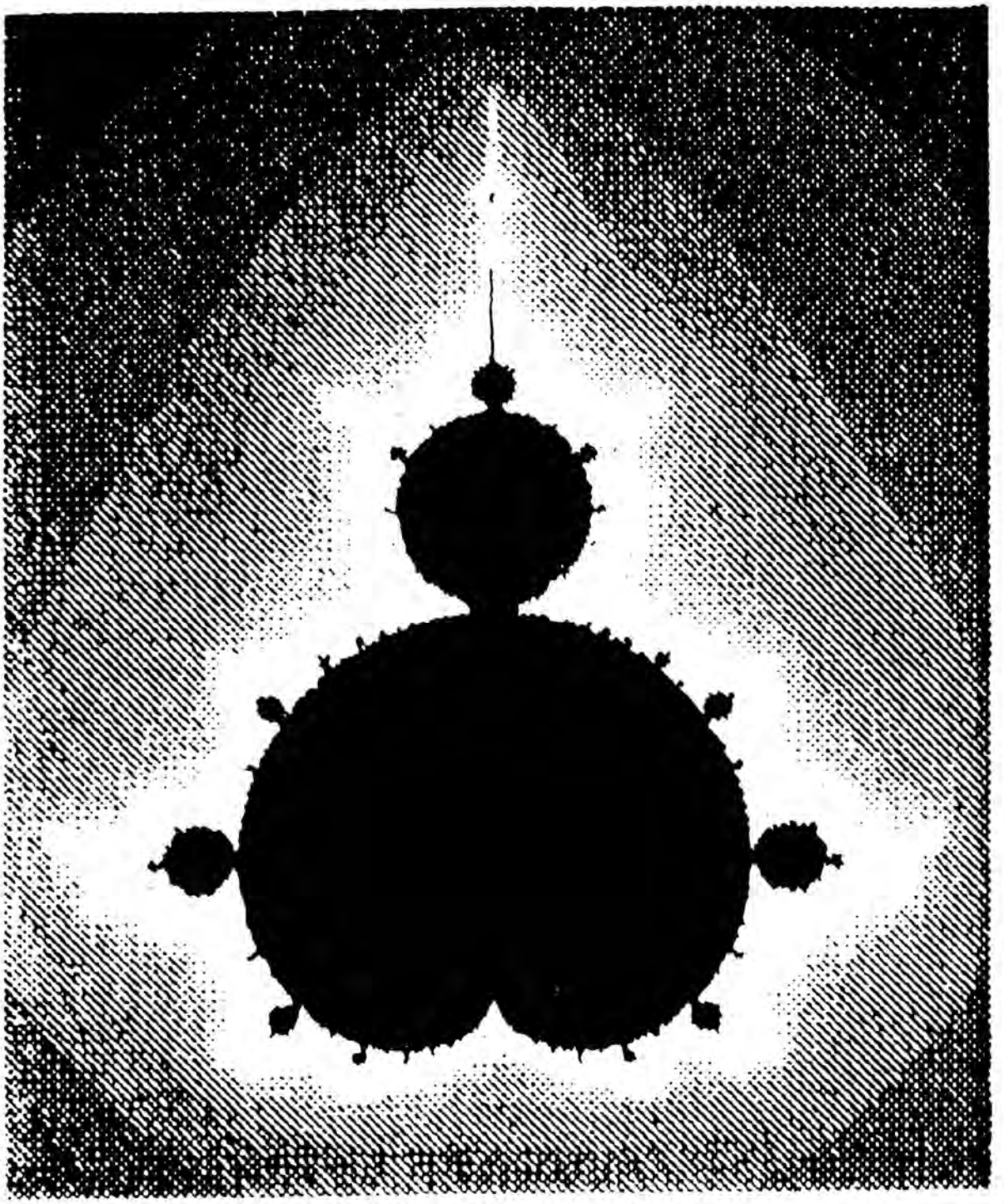
hi′er-ar′chal (-är′kăl), *a.* Pert. to a hierarch or hierarchy.

hi′er-ar′chic (-kĭk), **hi′er-ar′chi-cal** (-kĭ-kăl), *a.* [Cf. F. *hiérarchique.*] Pertaining to a hierarchy.

hi′er-ar′chism (hī′ĕr-är′kĭz′m), *n.* The principles or authority of a hierarchy. — **hi′er-arch′ist** (-kĭst), *n.*

i

ITERATION



i is for iteration

The iterative paradox, the (w)hole in the center of our logics, the potential chaos of the missing information applies naturally to many if not most of the things we think about,

[Briggs & Peat 1989: 76

>

[Gleick 1987

The Mandelbrot set is graphed by iterating the numbers in the complex number plane using the formula $z \rightarrow z^2 + c$. The points are "colored" according to how fast the value in the pixel goes towards infinity or zero. The process is computational intensive and impossible without computers.

.j .c

i'ter (ī'tẽr ; ĭt'ẽr ; 277), *n.* ; *pl* E. ITERS (ī'tẽrz ; ĭt'ẽrz), L. ITINERA (ĭ-tĭn'ẽr-*ȧ*). [L. See EYRE.] **1.** An eyre, or circuit, orig. of certain justices in England ; also, the record of the proceedings during an eyre (which see). *Obs. or Hist.*
2. A Roman road or highway.
3. *Anat.* A passage ; esp., the passage between the third and fourth ventricles in the brain ; the aqueduct of Sylvius.
4. *Rom. Law.* See VIA ; SERVITUDE.

it'er-ance (ĭt'ẽr-ăns), *n.* Iteration ; repetition.

it'er-ant (-ănt), *a.* [L. *iterans*, p. pr. of *iterare*.] Repeating ; iterating ; as, an *iterant* echo. *Bacon.*

it'er-ate (-ât), *a.* [L. *iteratus*, p. p. of *iterare* to repeat, fr. *iterum* again, prop. a compar. from the stem of *is* he, that ; cf. L. *ita* so, *item* likewise, also, Skr. *itara* other, *iti* thus. Cf. ITEM.] Iterated. *Obs.* — **it'er-ate-ly**, *adv.* *Obs.*

it'er-ate (-āt), *v. t.* ; IT'ER-AT'ED (-āt'ĕd) ; IT'ER-AT'ING (-āt'-ĭng). To utter or do a second time or many times ; to repeat ; as, to *iterate* advice ; to *iterate* an offense.

it'er-a'tion (-ā'shŭn), *n.* [L. *iteratio*.] **1.** Recital or performance a second time ; repetition. *Bacon.*

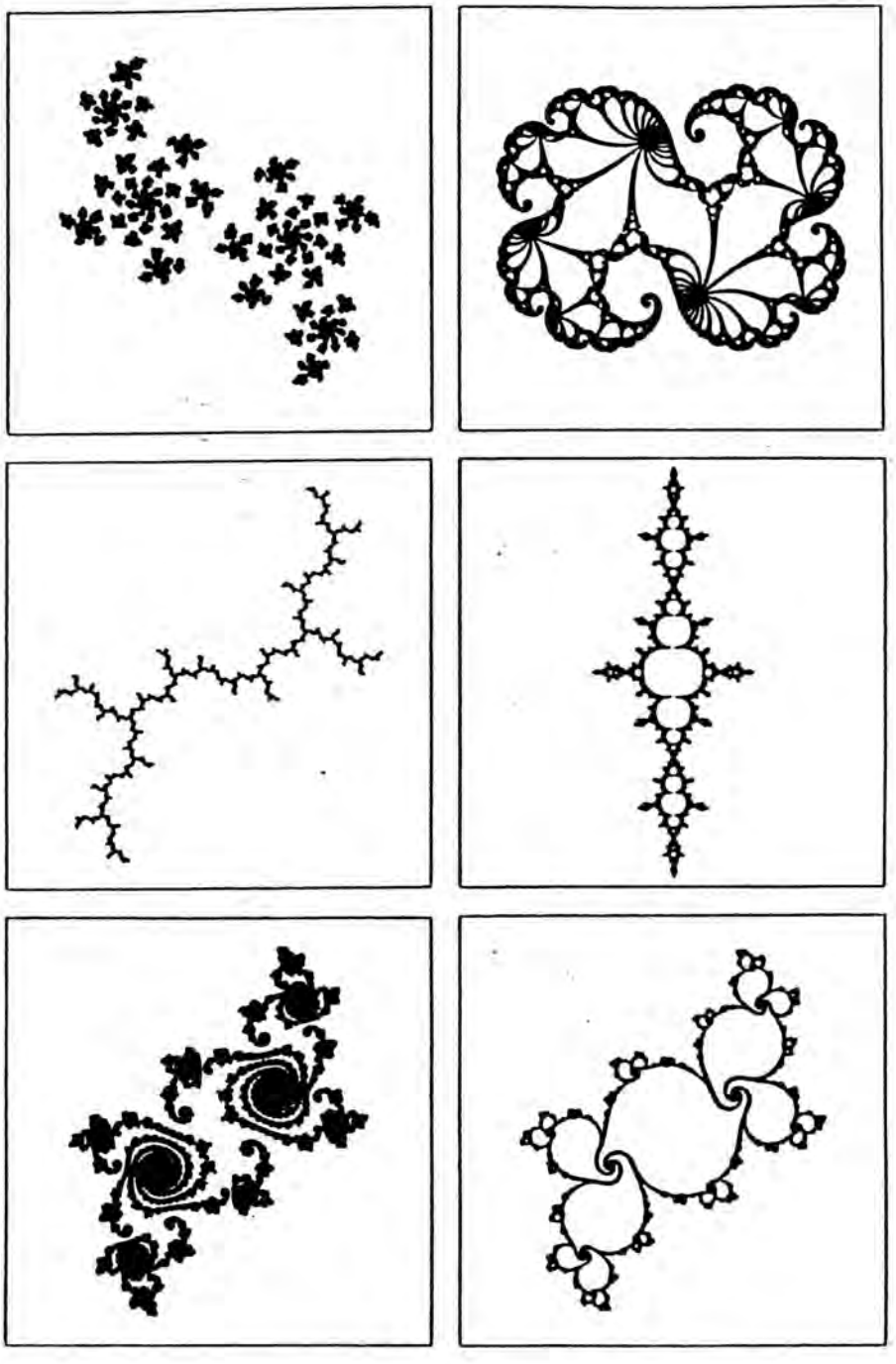
> What needs this *iteration*, woman ? *Shak.*

2. *Rom. Law.* The repetition of manumission that if duly made caused a Latin to become a Roman citizen.

it'er-a-tive (ĭt'ẽr-â-tĭv), *a.* [L. *iterativus* : cf. F. *itératif*.] **1.** Repeating ; repeated ; repetitious.
2. *Gram.* Denoting repetition ; frequentative.
Iterative function, *Math.*, result of one operation repeated.
— **it'er-a-tive-ly**, *adv.* — **it'er-a-tive-ness**, *n.*

j

JULIA SET



j is for Julia set

...Julia sets came in both flavors, some whole shapes and some dusts. The dusts, being fractal, have the peculiar property that no two pieces are "together"--because every piece is separated from every other by a region of empty space--yet no piece is "alone," since whenever you find one piece, you can always find a group of pieces arbitrarily close by.

[Gleick 1987: 228

>

[Gleick 1987

Exploring the complex plane uncovers density distinctions as in the Julia set where there are areas of low and high density. The patterns emerge out of the meeting and attracting or repelling of the imaginary and real numbers.

.i .c

group (grōōp), *n.* [F. *groupe*, It. *gruppo*, *groppo*, cluster, bunch, packet, group; of G. origin: cf. G. *kropf* craw, crop, tumor, bunch. See CROP, *n.*] **1.** *Fine Arts.* Two or more figures forming a design or taken together as a distinctive unit in a more complicated design; as, the Laocoön *group*; a *group* of soldiers in a battle scene.

2. *Music.* **a** A number of eighth, sixteenth, etc., notes joined at the stems; — sometimes applied to any figure made up of a few short notes, esp. when sung to one syllable. **b** A division of an orchestra composed of one class of instruments; as, the wood-wind *group*.

3. An assemblage of persons or things regarded as a unit because of their comparative segregation from others; a cluster; aggregation; as, a *group* of trees or of islands.

4. An assemblage of objects in a certain order or relation, or having some resemblance or common characteristic; as, *groups* of strata. See GEOLOGY, *Chart*.

5. *Chem.* An assemblage of atoms forming part (esp. a minor part) of a molecule; a radical, as, a methyl *group* (CH_3); the alcohol *group* (OH).

6. *Biol.* Any assemblage of animals or plants having natural relationship to each other.

7. *Math.* **a** See DISTRIBUTION. **b** A set of operations (generally substitutions) and their inverses, of which the product of any two or more is itself one of the set. Subsidiary necessary conditions are: $(st)u = s(tu)$, i. e., the associative law must be obeyed; if either $st = ut$ or $ts = tu$, then $s = u$; if in $st = u$ any two of the operations belong to the set, so must the third.

group of an equation, *Math.*, a transitive substitution group, of the same degree as the irreducible equation, that changes no function of the roots that is expressible rationally through the coefficients, but changes every other.

group (grōōp), *v. t.*; GROUPED (grōōpt); GROUP'ING. [Cf. F. *grouper*. See GROUP, *n.*] To form a group of; to arrange or combine in a group or in groups, often with reference to mutual relation and the best effect.

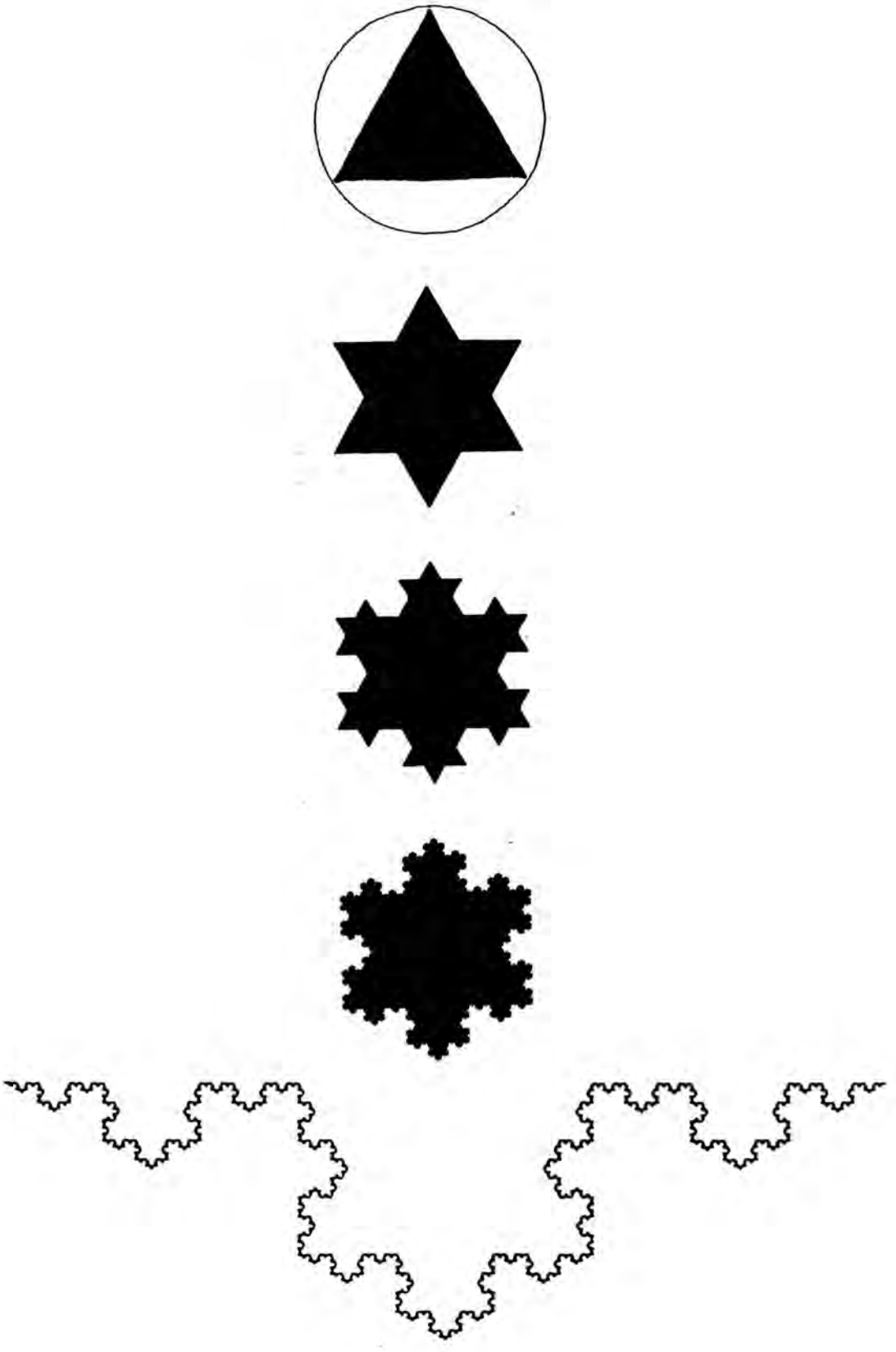
> The difficulty lies in drawing and disposing, or, as the painters term it, in *grouping*, such a multitude of different objects. *Prior.*

grouped columns, *Arch.*, three or more columns placed upon the same pedestal.

group, *v. i.* To form a group; to be a member of a group.

k

KOCH CURVE



k is for Koch curve

On reflection, it becomes apparent that the Koch curve has some interesting features. For one thing, it is a continuous loop, never intersecting itself, because the new triangles on each side are always small enough to avoid bumping into each other. Each transformation adds a little area to the inside of the curve, but the total area remains finite, not much bigger than the original triangle, in fact. If you drew a circle around the original triangle, the Koch curve would never extend beyond it.

[Gleick 1987: 99

Thus an infinitely long line surrounds a finite area as if being determined in one respect frees it in the other.

>
Using the Koch curve to illustrate fractal depth.

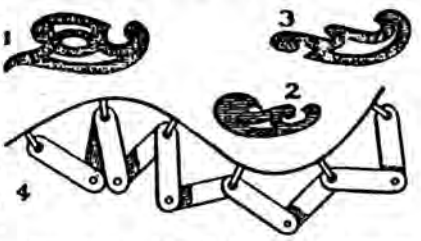
.a .i

curve (kûrv), *a.* [L. *curvus* bent, curved. See CURB.] Bent continuously without angles; curved; as, a *curve* line.

curve, *n.* [See CURVE, *a.*, CURB.] **1.** A bending without angles; that which is bent; a flexure; as, a *curve* in a road. **2.** *Math.* Analytically, a line or lines that may be precisely defined by an equation or equations; geometrically or kinematically, the path of a point gliding along an axis round which turns a plane while the axis turns round the point in the plane. Geometrically a curve is the intersection of two surfaces, or the path of a moving point, or the envelope of a moving line; analytically, it is a simply infinite system of points or of lines, according as its equation is in point or line coördinates. If a point glides continuously on a line that turns continuously about the point, the same curve is traced by the point and enveloped by the line (*Plücker*).

☞ The broadest accepted definition of a plane curve is: An assemblage of points that may be set in continuous one-to-one correspondence with the points (including the ends) of a line segment or with the points of a circle according as the curve is open or closed (*Hurwitz*).

3. A curved ruler of any of various forms or kinds used by draftsmen.



Curve, 3. 1, 2, 3 French Curves; 4 Flexible Curve consisting of a flexible strip of steel with devices to hold it at a given curve.

4. *Baseball.* A ball so thrown that its course is a curve different from that ordinarily caused by the force of gravity acting on a projectile; also, the deflection from the ordinary course. This effect is caused by the rapid rotation of the ball and the resistance of the air. If the ball bends toward the (right-handed) batter it is called an **in curve**, or **in**; if away, an **out curve**, or **out**; if upward, an **up shoot**; and if downward, a **drop**. **curve of a complex,** *Math.*, the curve enveloped by the lines common to the complex and a plane (hyperpencil). — **c. of double curvature,** *Math.*, one not lying in a plane; in general, one having no four consecutive points in a plane; a twisted or tortuous curve. — **c. of equal approach,** *Math.*, one along which vertical descent under gravity varies as the time. — **c. of frequency of error, c. of probability.** See PROBABILITY CURVE. — **c. of pursuit,** *Geom.*, a curve described by a point moving always directly towards or from a second point, which is itself moving according to some law. — **c. of quickest descent.** See BRACHISTOCHRONE. — **c. of style.** = STYLE CURVE.

1

LOVE

I is for Love

How now, my love! Why is your cheek so pale?
How chance the roses there do fade so fast?

Ay me! For aught that I could ever read,
Could ever hear by tale or history,
The course of true love never did run smooth;
But, either it was different in blood-

Or else misgraffed in respect of years-
Or else it stood upon the choice of friends-

Or if there were a sympathy in choice,
War, death , or sickness did lay siege to it,
Making it momentary as a sound,
Swift as a shadow, short as any dream,
Brief as the lightning in the collied night,
That , in a spleen, unfolds both heaven and earth,
And ere a man hath power to say"behold!"
The jaws of darkness do devour it up:
So quick bright things come confusion.

[MND I.i.128-149

Well , personally , I've seen
enough of people who die for
an idea. ... What interests me
is living and dying for what
one loves.

[Camus 1972:153

Love is a strange attractor.

>

[Hoffman 1972

love (lŭv), *n.* [ME. *love*, *luve*, AS. *lufu*; akin to E. *lief*, be*lieve*, L. *lubet*, *libet*, it pleases, Skr. *lubh* to be lustful. See LIEF.] **1.** A feeling of strong personal attachment induced by that which delights or commands admiration, by sympathetic understanding, or by ties of kinship; ardent affection; as, the *love* of brothers and sisters.

2. Manifestation of desire for, and earnest effort to promote, the welfare of a person, esp. as seen in God's solicitude for men and in men's due gratitude and reverence to God.

Keep yourselves in the *love* of God. *Jude* 21.

3. Strong liking; fondness; good will; — usually applied to persons, as in greetings and the like; to objects of ideal regard; as, *love* of learning; *love* of freedom; or to objects having a more or less ideal significance; as, *love* of country; *love* of money.

Love, and health to all. *Shak.*

4. Tender and passionate affection for one of the opposite sex; as, to marry without *love;* also, an instance of love; a love affair; as, the days of his first *love;* the *loves* of the gods.

5. Sexual passion or, *Rare*, its gratification.

6. The object of affection; — often employed in endearing address. "Trust me, *love*." *Dryden.*

Open the temple gates unto my *love*. *Spenser.*

7. [*cap.*] Cupid, or Eros, as the god of love; sometimes, Venus.

Therefore do nimble-pinioned doves draw *Love*. *Shak.*

8. A thin silk stuff. *Obs.*

9. The virgin's-bower. *Dial. Eng.*

love (lŭv), *v. t.;* LOVED (lŭvd); LOV'ING (lŭv'Ing). [AS. *lufian*. See LOVE, *n.*] **1.** To have love for; to experience or manifest love for; to devote one's love to; to be in love with.

Thou shalt *love* the Lord thy God with all thy heart, and with all thy soul, and with all thy mind *Matt.* xxii 37.

Thou shalt *love* thy neighbor as thyself. *Matt.* xxii. 39.

There 's none I *love* like thee. *Tennyson.*

2. To give or experience (love). *Rare.*

3. To take delight or pleasure in; to have a strong liking or desire for, or interest in; to be pleased with; to like; as, to *love* books; to *love* adventures.

Wit, eloquence, and poetry,
Arts which I *loved* *Cowley.*

4. To show love for by caressing; — a childish use.

5. To thrive in; as, the rose *loves* sunlight.

Syn. — See LIKE.

love, *v. i.* To have the feeling of love; esp., to experience or manifest love for one of the other sex; to be in love.

'T is better to have *loved* and lost,
Than never to have *loved* at all. *Tennyson.*

VI

METAPHOR

met'a-phor (mĕt'ȧ-fŏr), *n.* [F. *métaphore*, L. *metaphora*, fr. Gr. μεταφορά, fr. μεταφέρειν to carry over, transfer; μετά beyond, over + φέρειν to bring, bear. See META-; BEAR to carry.] *Rhet.* A figure of speech by which a word or phrase literally denoting one kind of object or idea is applied to another by way of suggesting a likeness or analogy between them; the transference of terms denoting one thing to the expression of another; as in "the ship *plows* the sea;" "a *volley* of oaths." A metaphor may be regarded as a compressed simile, the comparison implied in the former being explicit in the latter. Thus compare "a marble brow" with "a brow white like marble."
Syn. — See COMPARISON.

M is for metaphor

And as imagination bodies forth
The forms of things unknown, the poet's pen
Turns them to shapes, and gives to airy
nothing a local habitation and a name.
[MND V.i.14-18

Metaphor and symbols will
become a program for technical
transformation, and invented
technology will be the new
metaphors and symbols of the
world.
[Turner 1985: 234

The B words were a sort of
verbal short hand, often packing
whole ranges of ideas into a few
syllables and at the same time
more accurate and forcible then
ordinary language.
[Orwell 1977: 249

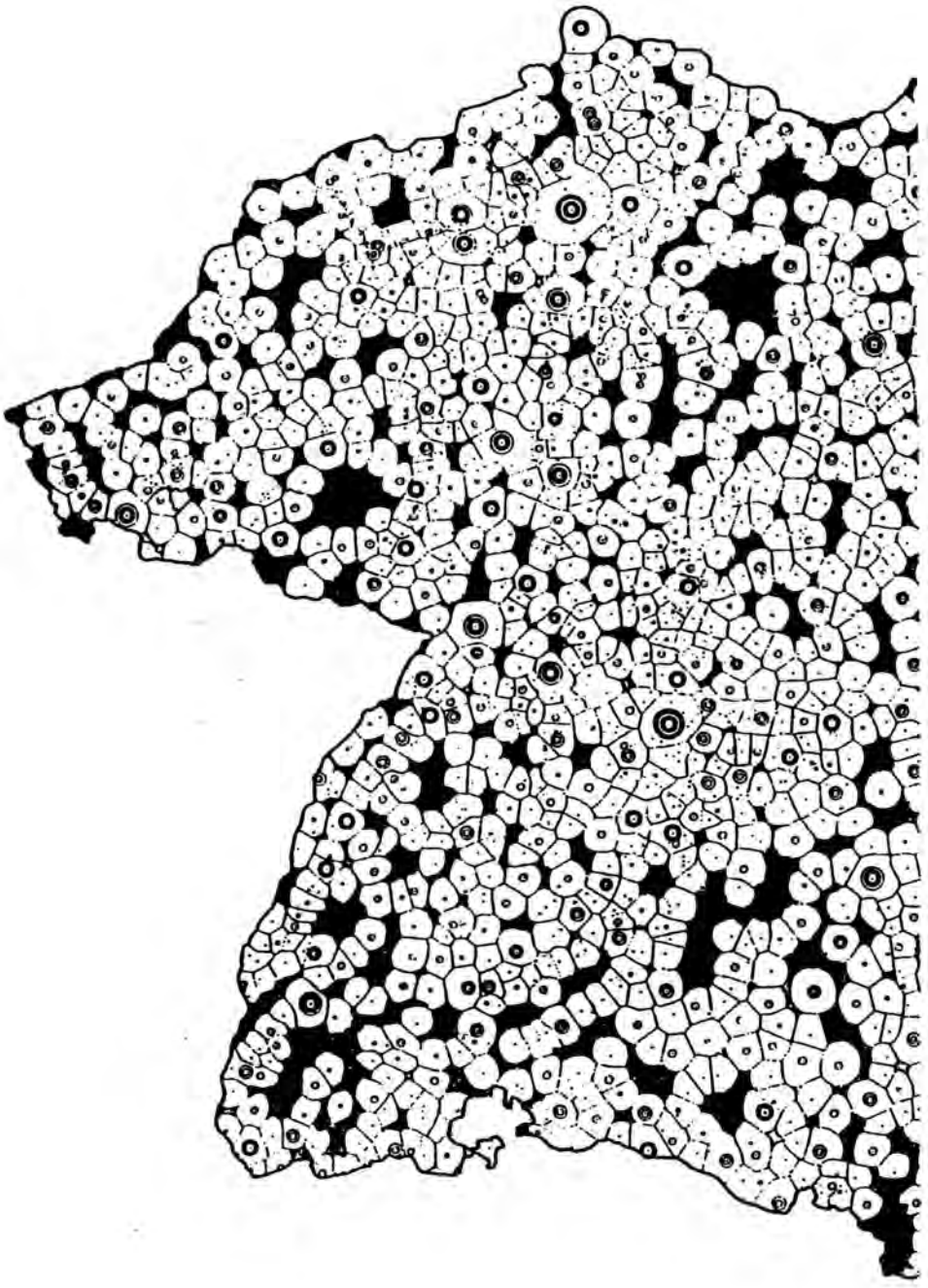
Metaphors model abstractions into
understanding. Metaphor explores
the space between known and
unknown, where learning happens.

> [W2-a:1918

.a .c

11

NATURE



N is for nature

...[The] Nature from which we were supposed to be alienated never existed: The great quantum experiments... show that Nature has not made up its own mind about what it *really* is, and is quite happy to have us help it do so. That whole tradition of philosophy which saw us as cut off from our "true" way of being has in fact collapsed, and simply has not realized it yet. *We* are Nature, and we are as at home in the world as anything has ever been at home...

[Turner 1985: 215

With light poised and counterpoise, Nature oscillates within her proscribed limits, yet thus arise all the varieties and conditions of the phenomena which are presented to us in space time.

Goethe in
[Gleick 1987: 164

>

[Christaller 1966

Cities and towns in central place theory - human settlement patterns as a multi-cellular organism

.a .p

na'ture (nā'tûr), *n.* [F., fr. L. *natura*, fr. *natus* born, produced, p. p. of *nasci* to be born. See NATION.] **1.** Birth; origin. In James iii. 6, translating the Greek γένεσις.

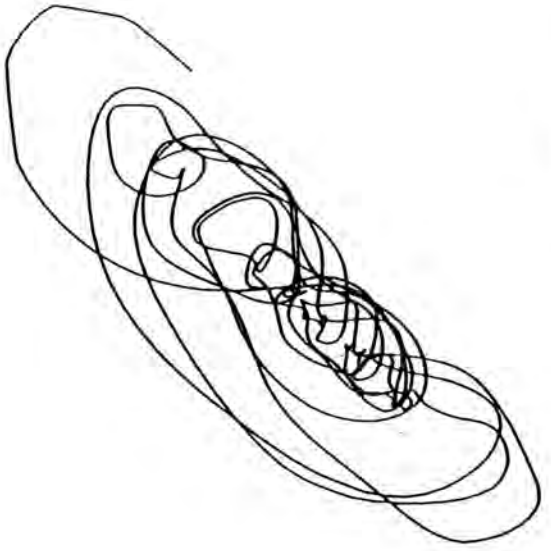
2. That which is the source or essence of life; creative force; the sum and order of causes and effects in time and space; the powers which produce existing phenomena, whether in the total or in detail; the agencies which carry on the processes of creation or of being, often conceived of as a single and separate entity, embodying the total of all finite agencies and forces as disconnected from a creating or ordering intelligence. In a metaphysical sense, the source or essence of the life of the universe; what appears and acts as forces, energies, laws.

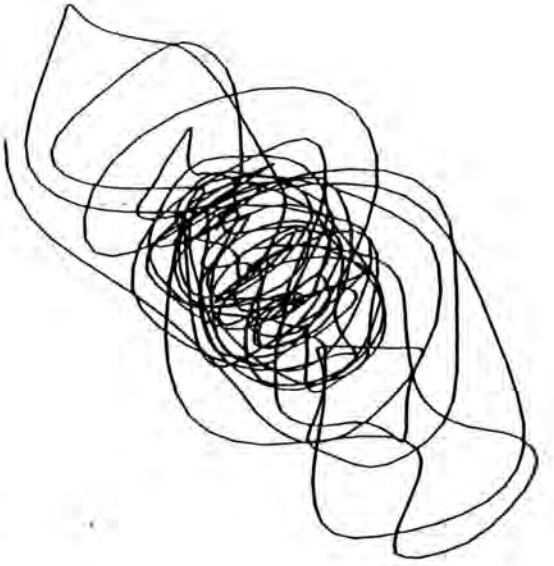
> So priketh hem *nature* in hir corages. *Chaucer.*
> What *nature* hath set in hir lawe
> That mai no mannes miht withdrawe. *Gower.*

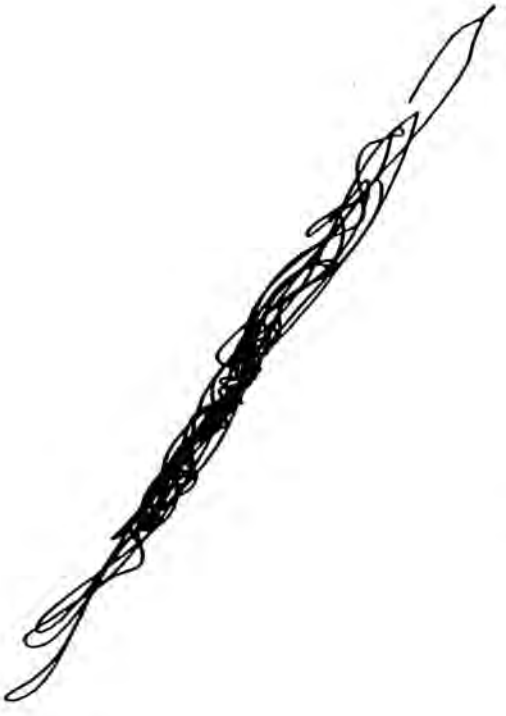
3. That which is produced by natural forces; the existing system of things in time and space; the world of matter, or of matter and mind; creation; the universe. The conception of *nature* (Gr. φύσις; L. *natura*) has been confused by the mingling of three chief meanings adopted with the word into English, viz.: (1) Creative or vital force; = def. 2. (2) Created being in its essential character; kind, sort; = def. 5. (3) Creation as a whole, esp. the physical universe; = def. 3. The main ambiguity is between *nature* as active or creative and *nature* as passive or created. In the original animistic view, the active, vitalistic conception prevailed; but Plato sharply distinguished the passive material from the active formal element, and Aristotle continued the distinction in the conception of a moving cause, or God, as separate from the moved physical universe, or Nature. This antithesis of the moving cause and its effect is all but obliterated in pantheistic and naturalistic views. It appears in the pantheism of Spinoza, but the distinction of *natura naturans* and *natura naturata* serves only to discriminate two elements or aspects of the one organic being or substance. The two elements, in the forms of matter and energy, are retained in the modern physical or mechanical view, wherein nature appears as a material universe acting according to rules, but to all intents independent of God or purposive cause. Nevertheless, the derivation and associations of the word prove a fruitful source of ambiguity, often conveying a deceptive implication of that animistic or zooidal view which still appears in the popular and poetic conception of *nature* as merely *animate nature*, i. e., as the world of plants and animals (cf. NATURALIST). Cf. PHYSICAL.

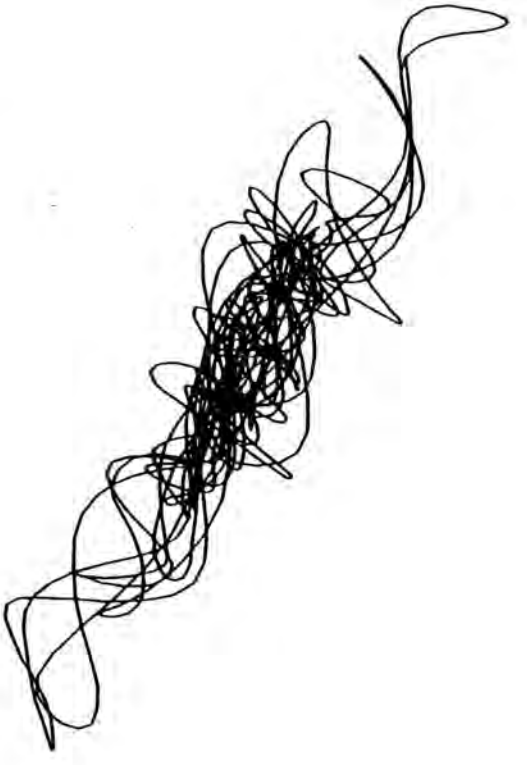
> The material mechanism which he [the naturalist] calls *Nature* would rank not as the profoundest reality there is to know: it would rather become — what indeed "machine" primarily connotes — an instrumentality subservient to the "occasions" of the living world of ends; and so regarded, it would cease to be merely calculable, and would be found intelligible as well.
>
> *James Ward (Encyc. Brit.).*

ORDER










is for order

My conclusion is that chaotic olfactory dynamics supports a global attractor, which is a storehouse of the means for expressing olfactory experience, and that it affords rapid access to any of its wings without requiring a time-consuming, exhaustive search through all its wings. Thereby chaos gives powerful vehicles to the central systems that abstract, generalize, and transmit low dimension and relevant information to the cognitive machinery involving attention and multimodal association. But the chaotic voice is not the information, merely the vehicle that carries it.

[Freeman 1990: 54-5

>

[Rapp 1990

Plots of attractors in a human brain, (above) subject at rest and solving an equation, (below) the same plots rotated 90 degrees.

.h .i

2. According to medieval angelology, any of the nine grades of angels; also, any similar class of beings.

6. *Math.* **a** Degree; thus, the *order* of a curve or surface is the same as the degree of its equation. **b** Of a differential equation, its highest index of derivation.

7. *Biol.* A category of classification ranking above the family and below the class. In botany, *order* or *natural order* was formerly exclusively applied to the category now more appropriately called *family*. The suffix denoting the latter is *-aceæ*, while the *order* of modern taxonomists has the suffix *-ales*. Thus the order Rosales is made up of the Rosaceæ (rose family), Fabaceæ (bean family), Cæsalpiniaceæ (cassia family), Mimosaceæ (mimosa family), etc. *Order* and *family* are still used interchangeably by some botanists. In zoölogy no distinctive suffix for names of orders has been adopted.

8. See PETROGRAPHY.

9. Regular arrangement; any methodical or established succession or harmonious relation; method; system; as: of material things, like the books in a library; of intellectual notions or ideas, like the topics of a discourse; of periods of time or occurrences, and the like. Hence: **a** A condition in which everything is so arranged as to play its proper part; as, "*Order* is Heaven's first law." *Pope.*

Bright-harnessed angels sit in *order* serviceable. *Milton.*

b The fixed arrangement of phenomena, both physical and psychical; — used esp. in such phrases as "moral *order*," "*order* of nature," "*order* of things," etc.

10. *Eccl.* A prescribed form of service, as for a rite; as, the *order* of confirmation.

11. Customary mode of procedure; established usage or method; as, the *order* of brewing. *Obs.*, except as used of procedure in debate, the conduct of deliberative bodies, etc.; as, he raised a point of *order;* the speaker is out of *order*.

12. Conformity to law or decorum; freedom from disturbance; general tranquillity; public quiet; rule of law or proper authority; as, to preserve *order* in a community.

13. Condition in general; normal state; as, the house is in *order;* in good *order;* in bad *order;* out of *order*.

14. A rank, row, or series. *Obs. or Archaic.*

15. *Mil.* Position of order arms (see ORDER ARMS).

16. Action suited to a particular end; as, they took *order* to avoid disaster. *Obs. or Archaic.*

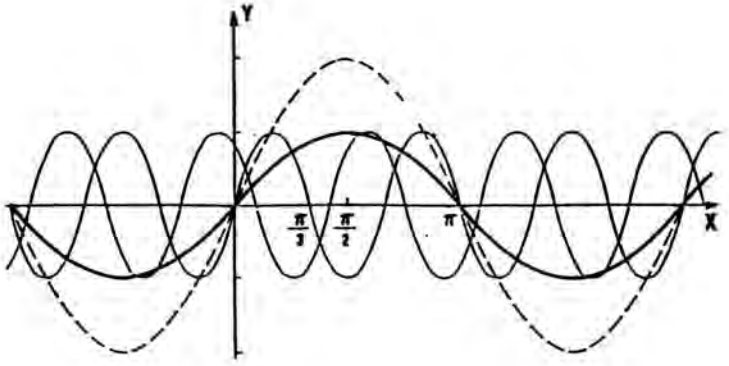
17. A putting or keeping in order; regulation; control. *Obs.*

18. A rule or regulation made by competent authority; also, a command; mandate; precept; direction.

Upon this new fright, an *order* was made by both houses for disarming all the papists in England. *Clarendon.*

P

PERIODIC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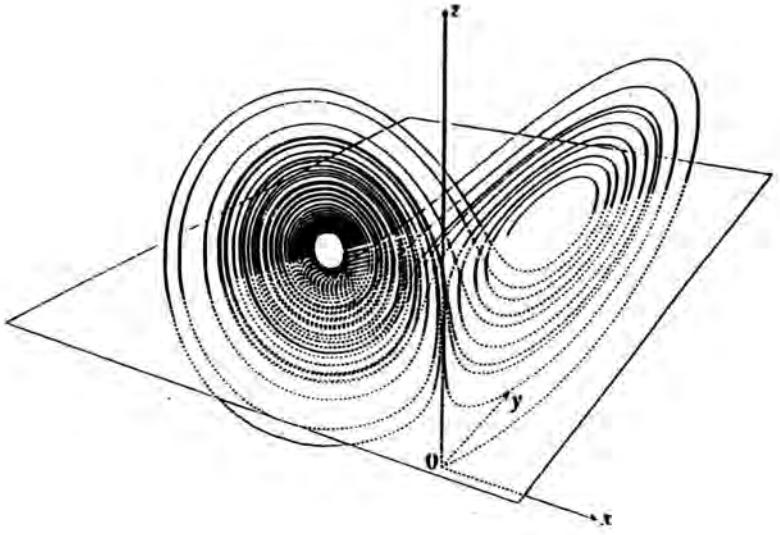
z
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P is for periodic

The fixed point andthe periodic loop are attractors, and there is nothing strange about them. The *quasi-periodic* attractor representing a finite number of modes is also not strange. But the Lorenz attractor is strange, as are many attractors introduced by Smale. The strangeness comes from the following features, which are not mathematically equivalent but usually occur together in practice.

First strange attractors look strange: they are not smooth curves or surfaces but have "non-interger dimension" they are *fractal* objects. Next, and more importantly, the motion on a strange attractor has sensitive dependence on initial condition. Finally, while strange attractors have only finite dimension, the time-frequency analysis reveals a continuum of frequencies.

[Ruelle 1991: 64

>(Above) Periodic motion as a time series graph. (Middle) periodic astronomical motion. (Below) the Lorenz attractor.

.a .d .f .t

pe'ri-od (pē'rĭ-ŏd), *n.* [L. *periodus*, Gr. περίοδος a going round, a way round, a circumference, a period of time; περί round, about + ὁδός a way: cf. F. *période*.] **1.** Length of existence; duration. *Obs. or R.*

To make plants more lasting than their ordinary *period*. *Bacon.*

2. A portion of time as limited and determined by some recurring phenomenon, as by the completion of a revolution of a heavenly body; a division of time, as a series of years, months, or days, in which something is completed, and ready to recommence and go on in the same order.

3. Specif. **a** *Med.* The time of the exacerbation and remission of a disease, or of the paroxysm and intermission. **b** *Physiol.* Menses; — usually in *pl.* **c** *Astron.* The time in which a planet or satellite revolves about its primary; as, the *period* of the earth. **d** *Physics.* The time between a phase of vibration and its recurrence; as, the *period* of sound waves.

11. *Math.* **a** One of several similar sets of figures or terms usually marked by points or commas placed at regular intervals, as in numeration, in the extraction of roots, and in circulating decimals; a degree. **b** A magnitude p for which the equation $f(z \pm p) = f(z)$ holds for all values of z. If it does not hold for any submultiple of p, the period is **primitive**.

pe'ri-od'ic (pē'rĭ-ŏd'ĭk), *a.* [L. *periodicus*, Gr. περιοδικός: cf. F. *périodique*.] **1.** Of, pertaining to, or performed in, a period, or regular revolution, of a heavenly body; as, the *periodic* time or motion of a planet.

2. Characterized by periods; occurring at regular stated times; acting, happening, or appearing, at fixed intervals; loosely, recurring; intermittent; as, *periodic* epidemics.

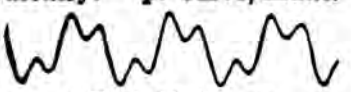
The *periodic* return of a plant's flowering. *Henslow.*

3. *Rhet.* Of or pertaining to a period; expressed in, or characterized by, periods.

4. = PERIODICAL, 4. *Rare.*

5. Of or pertaining to a period of time. *Rare.*

periodic comet, *Astron.*, a comet that moves about the sun in an elliptic orbit. — **p. current**, *Elec.*, a current whose strength or direction varies periodically. — **p. curve**, *Math. & Physics*, a curve formed by the continued repetition of some part of itself, as the sinusoid; the graph of a periodic function.

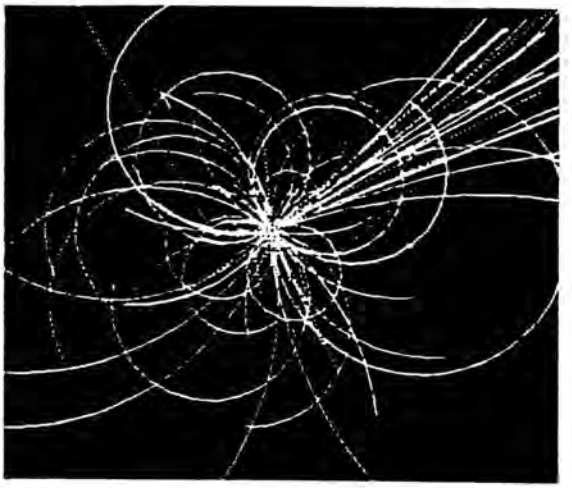


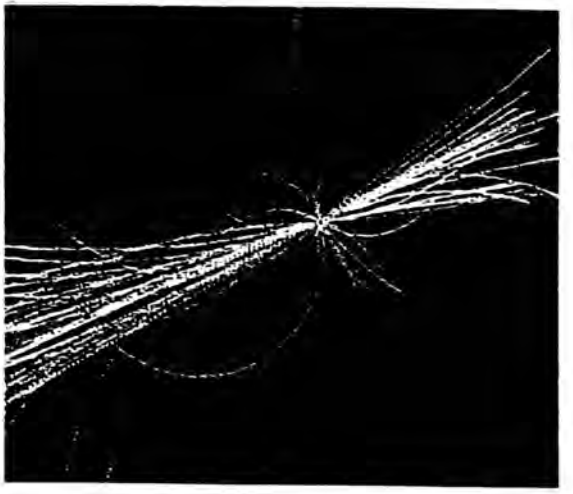
A Periodic Curve.

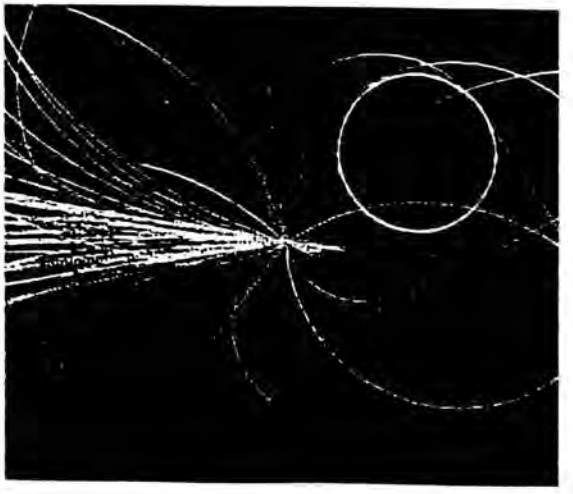
— **p. function**, *Math.*, a function whose value is not changed by increasing or decreasing its argument by any multiple of a constant, called the period; as, the trigonometric functions, since $\sin(x \pm n \cdot 2\pi) = \sin x$, $\tan(x \pm n\pi) = \tan x$. More generally, a function unaffected by putting for its argument some algebraic function of the argument. — **p. law**, *Chem.*, the generalization that the properties, physical and chemical, of the elements are periodic functions of their atomic weights. It is called also *Mendeleeff's law*. Such a relationship between properties and atomic weights was recognized as early as 1829 by Döbereiner, who drew attention to certain groups of three closely related elements, the atomic weight of one of which is the mean of those of the other two, as in the case of calcium, strontium, and barium. Such groups are called **triads of Döbereiner**. In 1864 Newlands and Lothar Meyer independently arranged a number of the elements in order of their atomic weights in such a way as to bring out the fact that at the end of a certain *period* the same

9

QUANTUM







Q is for quantum

We now have, in physics, two theories of great power and interest: the theory of quantum phenomena and the theory of relativity. These two theories have their roots in mutually exclusive groups of phenomena. Relativity theory applies to macroscopic bodies such as stars. The event of coincidence, that is in ultimate analysis of collision, is the primitive event in the theory of relativity and defines a point in space-time, or at least would define a point if the colliding particles were infinitely small. Quantum theory has its roots in the microscopic world and, from its point of view, the event of coincidence, or of collision, even if it takes place between particles of no spatial extent, is not primitive and not at all sharply isolated in space-time. The two theories operate with different mathematical concept- the four dimensional Riemann space and the infinite dimensional Hilbert space, respectively.

quan'tum (kwŏn'tŭm), *n.*; *pl.* QUANTA (-tă). [L., neuter of *quantus* how great, how much. See QUANTITY.] **1.** Quantity; amount. "Without authenticating . . . the *quantum* of the charges." *Burke.*
2. Specif.: **a** A large quantity or amount. **b** A certain (specified) quantity or amount, esp. that allotted to one; a share or portion. **c** A thing having quantity; a body.
3. *Math.* A definite portion of any manifold or extent, limited by a mark or by a boundary. *W. K. Clifford.*

So far, the two theories could not be united that is, no mathematical formulation exists to which both of these theories are approximations. All physicists believe that a union of the two theories is inherently possible and that we shall find it. Nevertheless, it is possible also to imagine that no union of the two theories can be found.

[Wigner 1960:11-12

Quantum mechanics implies that initial measurements are always uncertain and chaos ensures that the uncertainties will quickly overwhelm the ability to make predictions.

[Crutchfield 1986: 49

.n .c

r

RANDOM

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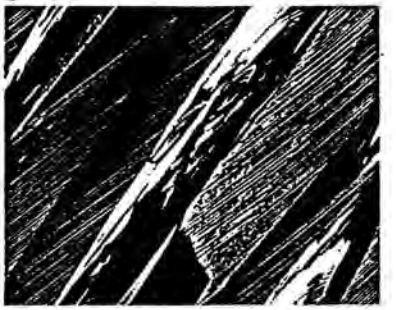

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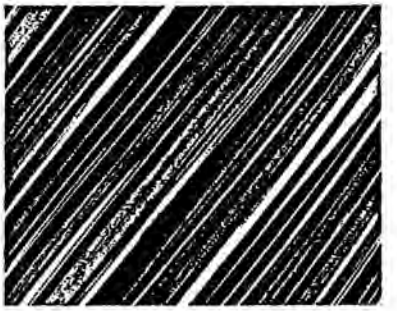

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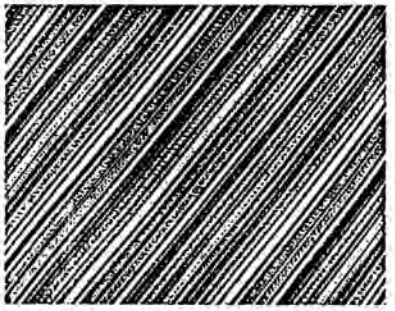

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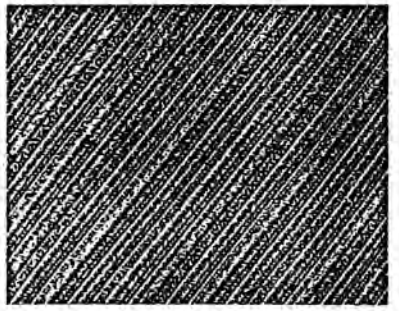

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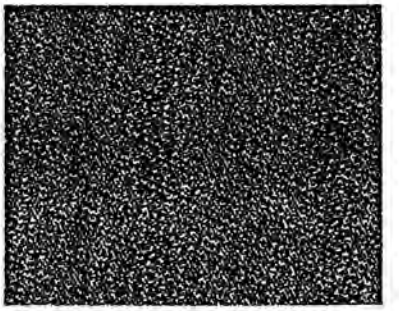

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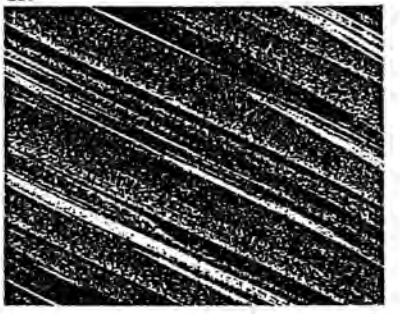

239

240

241

r is for random

...the universe is an economy
between randomness and order
that appears to both imitate
and distort itself with every
new creation.

[Argyros 1991: 342

>

[Crutchfield 1986

The random is not as unordered
as it once was. Chaos theory
provides a mathematical
technique that shows how, in
some circumstances, ordered
systems cycle through random
stages back towards self
similarity.

.w .o .n .i

ran'dom (răn'dŭm), *n.* [ME. *randon*, OF. *randon* force, violence, rapidity, a *randon*, de *randon*, violently, suddenly, rapidly; cf. OF. *randir* to run hard, to gallop; prob. of German origin; cf. G. *rand* edge, border, OHG. *rant* shield, edge of a shield, akin to E. *rand*, n. See RAND, *n.*] **1.** Force; violence; impetuosity. *Obs.*

The two kings newly fought with great *random*. *E. Hall.*

2. A rush, spurt, or stream, as of speech, water, fire. *Obs.*

3. A haphazard or random course or progress.

4. In technical uses: **a** *Gun.* The range of a gun or projectile; also, the elevation given to a gun. *Obs.* **b** *Mining.* The direction of a rake vein. **c** *Print.* A sloping board set on top of a frame to hold galleys of type, etc., for use in making up. *Eng.* **d** *Weaving.* A trial pattern.

at random. **a** Without definite direction, rule, or method; at haphazard; aimlessly; as, a shot fired *at random*.

Counsels, when they fly
At random, sometimes hit most happily. *Herrick.*

b Without restraint or attention; at liberty; neglected. *Obs.* **c** *Gun.* With any elevation or depression of the gun; — contrasted with *point-blank*. *Obs.*

ran'dom, *a.* **1.** Going at random or by chance; acting, done, or made, at hazard, or without settled direction, aim, or purpose; left to chance; haphazard; as, a *random* guess.

So sharp a spur to the lazy, and so strong a bridle to the *random*. *H. Spencer.*

2. *Masonry.* Irregular, as tooling; specif., consisting of stones of various height fitted together at random.

Syn. — Chance, stray, casual, fortuitous, accidental, aimless. — RANDOM, HAPHAZARD. RANDOM implies absence of fixed aim or purpose; HAPHAZARD heightens the implication of chance or accident; as, "My choice was as *random* as blindman's buff" (*Burns*); "They will throw out a *random* word in or out of season" (*Lamb*); "as [he] lazily turned the leaves of his *haphazard* reading" (*Lowell*); "whatever *haphazard* teaching of French there may have been" (*id.*). See ACCIDENTAL, VAGRANT.

random line, *Probability*, a line so chosen that the infinitesimal chance of its meeting any line segment varies as the length of the segment. — **r. point**, *Probability*, a point so chosen that the chance of its falling within any closed surface varies as the volume inclosed. — **r. shot**, a shot not directed or aimed toward any particular object.

— **ran'dom-ly**, *adv.* — **ran'dom-ness**, *n.*

space

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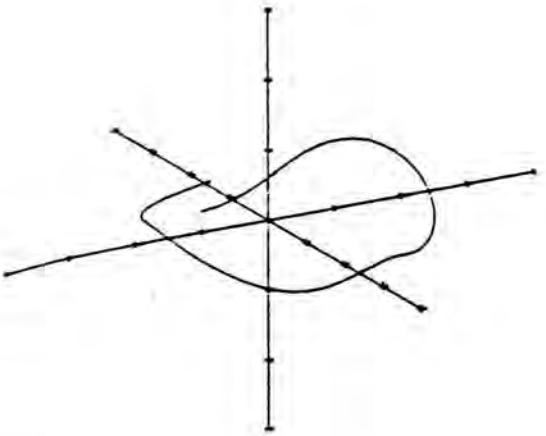
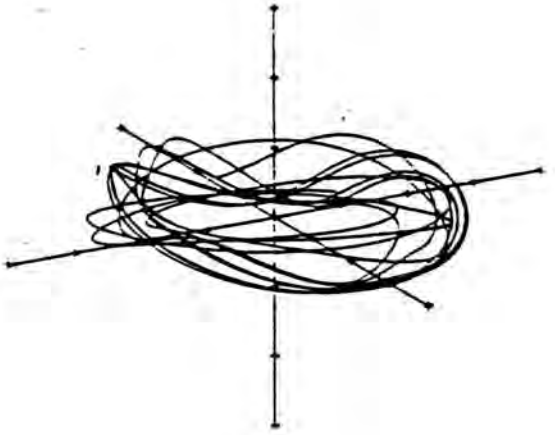
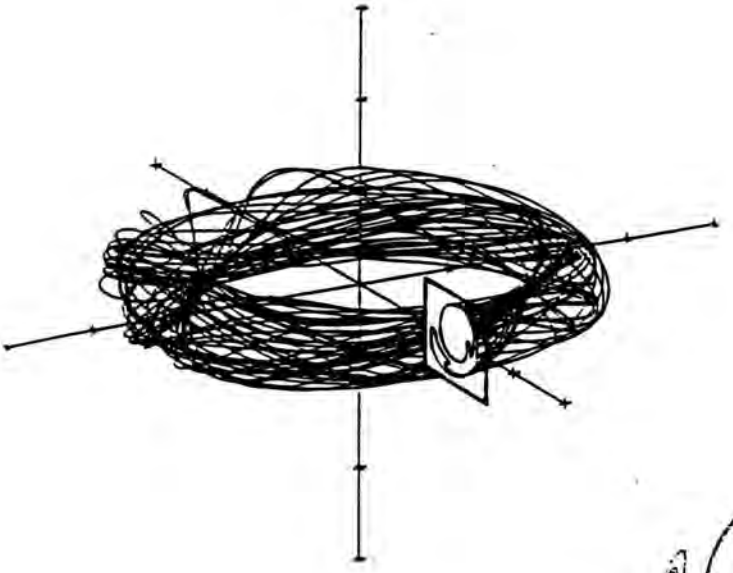
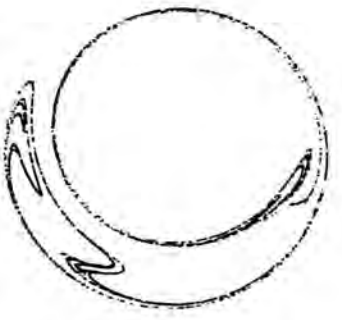
TOPOLOGY









t is for topology

Why fractal geometry is different from topology:

The class of mathematical objects known as the fractal curves and surfaces includes curves drawn in a plane that are highly wiggly at all scales of magnification, as well as surfaces in space that are very strongly wrinkled, again at all scales. These objects are continuous--unbroken paths may be traced along them--and they lie within regions that are finite in extent, rather than featuring protrusions that extend to infinity. They do not possess derivatives...

[Heppenhiemer 1988:17

>

[Gleick 1987

According to Ruelle the torus attractor is not strange but quasi-perodic. And, by the above definition, fractal not topological.

.a .f .s

to-pol′o-gy (tō-pŏl′ō-jĭ), *n.* [*topo-* + *-logy.*] **1.** A mnemonic method based on association of ideas with places. *R.*
2. Topographical study.
3. *Math.* **a** The doctrine of those properties of a figure unaffected by any deformation without tearing or joining; the theory of the invariants of the group or groups of continuous deformation; analysis situs. **b** The theory of knots.
— **top′o-log′i-cal** (tŏp′ō-lŏj′ĭ-kăl), *a.*

a-nal′y-sis si′tus (si′tŭs). [NL., lit., analysis of situation.] *Math.* That branch of mathematics which investigates the properties of a geometrical configuration that are independent of its form and size. Euler's theorem as to the number of vertices, edges, and faces of a polyhedron is a proposition of *analysis situs.*

UNIVERSAL

U is for universal

...chaos makes a powerful case for the possibility of resurrecting the concept of the universal.

[Argyros 1991: 340

The power of chaos theory, its universal promise, is the view it offers us of phenomena through a macroscope/microscope so that we see a relationships between the local *and* the global .

>
This 19th C. interpretation of a medieval wood block illustration shows a student seeking the invisible.

.p .d .q

u′ni-ver′sal (ū′nĭ-vûr′săl), *n.* **1.** The whole; the general system of the universe; the universe. *Obs.*

2. *Logic.* **a** A universal proposition. See UNIVERSAL, *a.*, 3.

In all induction the *universal* is the conclusion, in none a major premise, and in none the ground of either the being or the knowing of the particulars. *Thos. Case (Encyc. Brit.).*

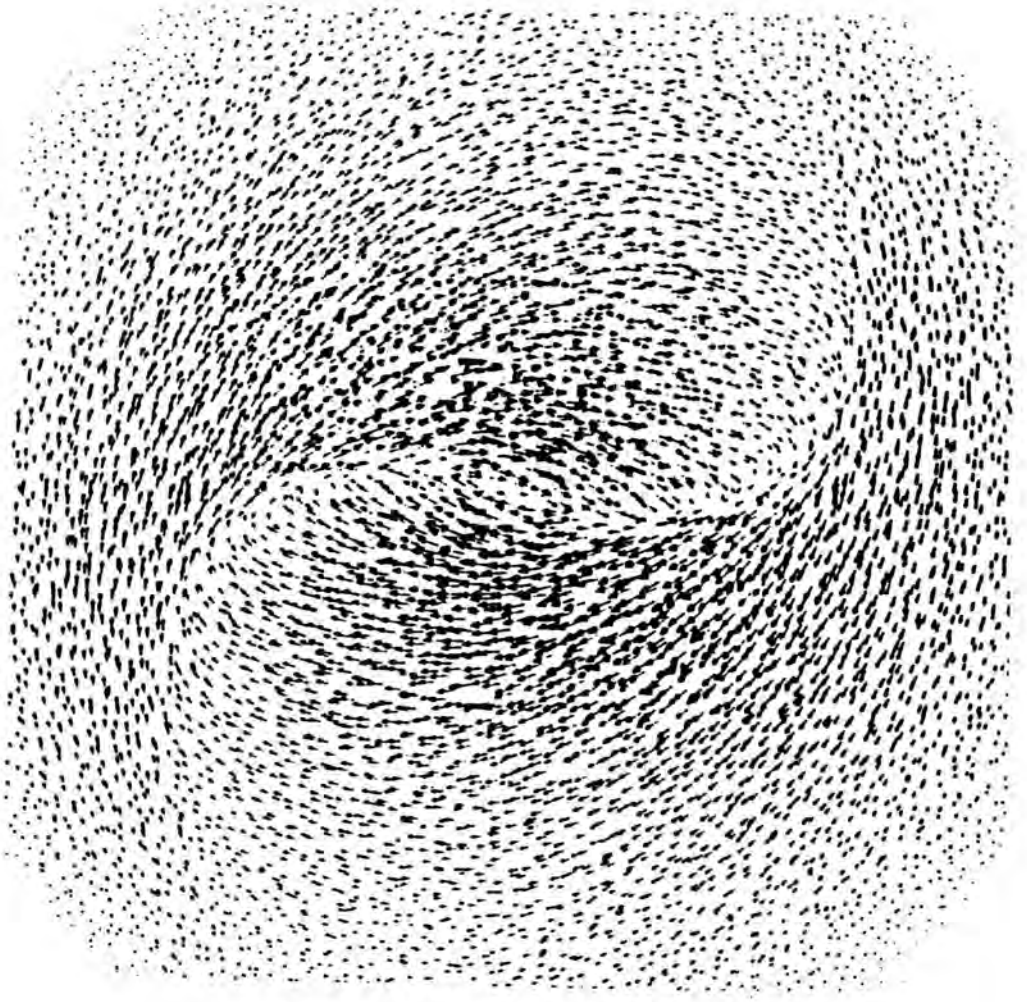
b One of the five predicables, namely, genus, species, difference, property, accident, named collectively *the universals.* **c** A general concept or that in reality to which it corresponds; an abstraction or an abstract and general term, whether conceived as a mere word or name (the nominalist view), as a truth, or predicate which may be truly thought or affirmed of reality (the conceptualist view), or as an actual character of reality (the realist view). The medieval controversy on the nature of *universals* derived its chief impetus from the importance of the problem in discussions of the nature of the Trinity. Extreme nominalists (as Roscelin), holding that only particular things can exist in nature, inferred the particularity and denied the unity of the persons of the Godhead; realists, recognizing universals as realities, maintained the essential unity of the divine nature. As a logical problem nominalistically treated, the controversy centered about the question of the reality of similarities or identities, classes being regarded as the only universals The *universal* is that element of things which remains when all differences are abstracted — universals as classes being therefore mere factitious unities. Is it, then, an independent reality common to all the individuals of a given class? The nominalistic solution of this problem in Scholasticism was that there is no physical unity corresponding to the universal, although there are physical similarities, but that the *universal* has a conceptual reality, though by itself this cannot furnish a sufficient account of actuality, or concrete being. That Plato's Ideas and Aristotle's Entelechies, regarded as self-activities, suggested originally the standpoint of realism is assumed in Hegel's philosophy, who regards the universal as the self-determined in the phase of determiner, while the particular is the self-determined in the phase of result from the action of the universal upon itself, forming an antithesis or contrast of activity and its result. Cf. REALISM, 1 a. *W. T. Harris.*

3. *Metaph.* Any metaphysical being which preserves or evinces an identity of nature through a series of changes or as embodying different relations, as the ego or self.

Self-consciousness, wherein the *universal*, or self, is the organic total of the facts of consciousness. *Josiah Royce.*

V

VECTOR



V is for vector

Phase space is "an ideal, often multidimensional, space of which the coordinate dimensions represent the variables required to specify the phase or state of the system" ([W2) It is technique used to model systems composed of large numbers of discrete particles.

The splitting into something discrete and something continuous seems to me a basic issue in all morphology.

[Weyl 1952:109

>

[Binney 1987

(above) A radiograph of a spiral galaxy. (below) This vector field image suggests the way dynamic systems are modeled. Every particle in the system exists in its own phase space.

.a .i .d .s

vec'tor (vĕk'tŏr), *n.* [L., a bearer, carrier, fr. *vehere*, *vectum*, to carry.] **1.** = RADIUS VECTOR.
2. *Math.* A directed magnitude, as a line segment, a force, or a velocity; the symbol of a definite translation from one point to another in space; the magnitude whose addition to a point in space transposes that point to another definite point. Vectors are said to be equal when their directions are parallel and their lengths equal. Cf. SCALAR

sca'lar (skā'lăr), *a.* [L. *scalaris* (cf. SCALARY). See SCALE a ladder.] **1.** Scalary. *Obs.*
2. *Math.* Following the laws of arithmetical algebra; — applied to numbers both real and ideal.
scalar function, *Math.*, a real numerical magnitude, one- or many-valued for each point of a three-dimensioned extent.
sca'lar, *n.* *Math.* **a** In quaternions, an undirected quantity, a pure real number; — disting. from a *vector*. By some, *scalar* is used to include imaginaries. **b** A scalar number.

phase (fāz), *n.* [NL. *phasis*. Gr. φάσις, fr. φαίνειν to make to appear: cf. F. *phase*. See PHENOMENON, PHANTOM; cf. EMPHASIS.] **1.** *Astron.* A particular appearance or state in a regularly recurring cycle of changes with respect to quantity of illumination or form of illuminated disk; as, the *phases* of the moon or planets. See MOON, *Illust.*
2. Any one of different and varying appearances of an object; any appearance or aspect of an object of mental apprehension or view; any of a number of varying aspects of a thing; as, the problem has many *phases*.
3. *Physics.* In uniform circular motion, simple harmonic motion, or in the periodic changes of any magnitude varying according to a simple harmonic law (as sound vibrations, alternating electric currents, etc.), the point or stage in the period to which the rotation, oscillation, or variation has advanced, considered in its relation to a standard position or assumed instant of starting. This relation is commonly expressed in angular measure, one cycle or period being 360°, or 2π (radians); thus, when the equation of the varying magnitude is $y = a \sin (\omega t - \epsilon)$, the phase is given by the angle $(\omega t - \epsilon)$, where ω is angular velocity and ϵ is the angle of epoch determining the phase of vibration, etc., when the time, t, is zero. If one complete cycle is taken as the unit, the phase is the angle $(\omega t - \epsilon)$ divided by 360°, or 2π, and is equal to the elapsed time divided by the period. Such periodic variations are well represented by sine curves, and the phase relations or the phases of two or more such quantities are shown by the relative positions of the crests and hollows of such curves. Magnitudes whose maximum values are simultaneous are said to be of the same phase or to be **in phase**; otherwise they are said to be of a different phase or **out of phase**, the difference between the times of their maxima (measured in angular measure or as a fraction of a period) being the phase difference. Two periodic quantities $a_1 \sin (\omega t - \epsilon_1)$ and $a_2 \sin (\omega t - \epsilon_2)$ have a phase difference of $\epsilon_2 - \epsilon_1$. Magnitudes whose phase difference is 180° are said to be **of opposite phase**. In electricity, a single alternating current is termed a **single-phase current**, whereas several currents differing in phase are termed **polyphase**, or **multiphase, currents**; thus in a three-phase system or apparatus three currents flow, differing in phase from each other by 120°; in a diphase system two currents flow, differing in phase by 90°, etc. A polyphase system is **balanced** when the currents of the several phases are equal.
4. *Phys. Chem.* A homogeneous, physically distinct portion of matter in a nonhomogeneous system; as, the three *phases*, ice, water, and aqueous vapor. A phase may be either a single chemical substance or a mixture, as of gases.

WHY?

IS,

wy

Belike for want of rain, which I could well
Beteem them from the tempest of my eyes.

O cross! Too high to be enthralled to low!

O spite! Too old to be engaged to young!

O hell! To choose love by another's eyes!

If then true lovers have been ever crossed,
It stands as an edict in destiny:
Then let us teach our trial patience,
Because it is a customary cross,
As due to love as thoughts and dreams and sighs,
Wishes and tears, poor Fancy's followers.
[MND I.i.130-155

Why ask? Why love? It is hard
wired into humans. Looking at
water, weather, and love we
explore the common boundaries
of color and form, truth and love,
liquid and gas, ordered and
random and other turbulent
transformations.

> [Schwenk 1976

.l .a

why (hwī), *adv.* [ME. *whi*, *why*, AS. *hwī*, *hwȳ*, instrumental case of *hwā*, *hwæt;* akin to Icel. *hvī* why, Dan. & Sw. *hvi;* cf. Goth. *hwē*. See WHO.] **1.** For what cause, reason, or purpose; on what account; wherefore; — used interrogatively.

> Turn ye, turn ye from your evil ways; for *why* will ye die, O house of Israel? *Ezek.* xxxiii. 11.

2. For which; on account of which; — used relatively.

> No ground of enmity between us known
> *Why* he should mean me ill or seek to harm. *Milton.*

3. For what reason or cause; on account of what; on what account; as, I know not *why* he left town so suddenly; — used as a compound relative. *Why* is sometimes used as an interjection or an expletive in expression of surprise or content at a turn of affairs; it is used also in calling. "*Why*, Jessica!" *Shak.*

> If her chill heart I cannot move,
> *Why*, I 'll enjoy the very love. *Cowley.*

for why, because; why. See FORWHY. *Obs. or Colloq.*

why, *n.* That which constitutes a reason or cause. "Every *why* hath a wherefore." *Shak.*

> The how and the *why* and the where. *Goldsmith.*

Summary:

Chaos an abyss, is the space between. Following catastrophe chaos explores what was previously unknowable, using computers. Computer modeling brings into focus self-similarity across disciplines which reveal universal connections between local and global phenomena in nature. Looking globally at nearly periodic dynamic systems in phase space presents patterns, strange attractors, which describe systems evolving in time. Chaos evolved by borrowing from topology the idea of "embedding space" but it treats the concept of dimension, temporality, and geometry in radically different ways. Using non-Euclidian geometry new hierarchies emerge which seemed random before. Julia sets and Koch curves develop through iteration the paradox of a bounded infinite space. Looking at an unbounded finite space through the micro-macroscope of chaos we see the relationship between quantum and astronomical scale. The view determines what is seen for example all systems appeared to go through randomness until bifurcations were mapped and an underlying order appeared. Between random and order lies a boundary space which is fractal. This boundary space resembles a liminal space or a threshold area where transformations occur through evolution. Metaphors bridge the thresholds relating the abstract to the real in literature and in mathematics. Love is such a metaphor as well as a strange attractor, the unknown that draws us forth.

Appendix I

Charting the Abecedarium

Appendix II

Chaos Narrative

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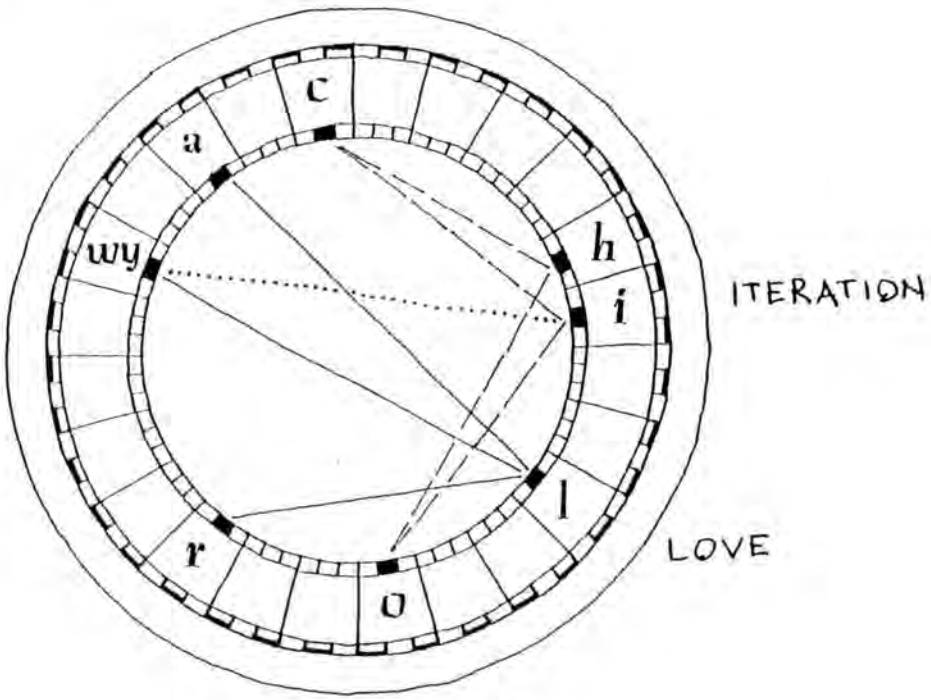

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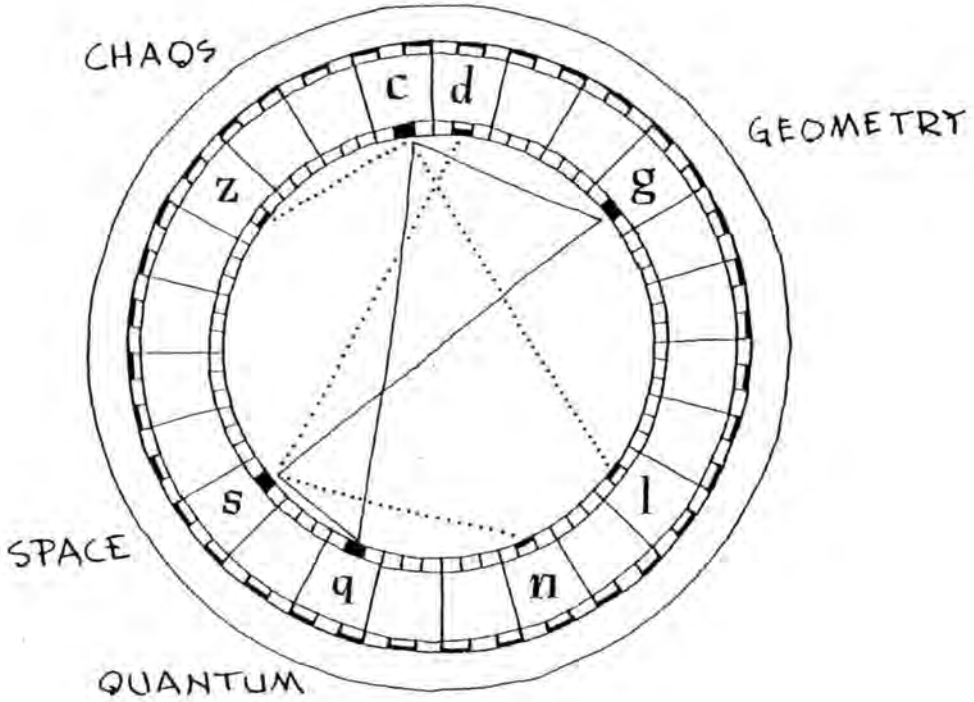

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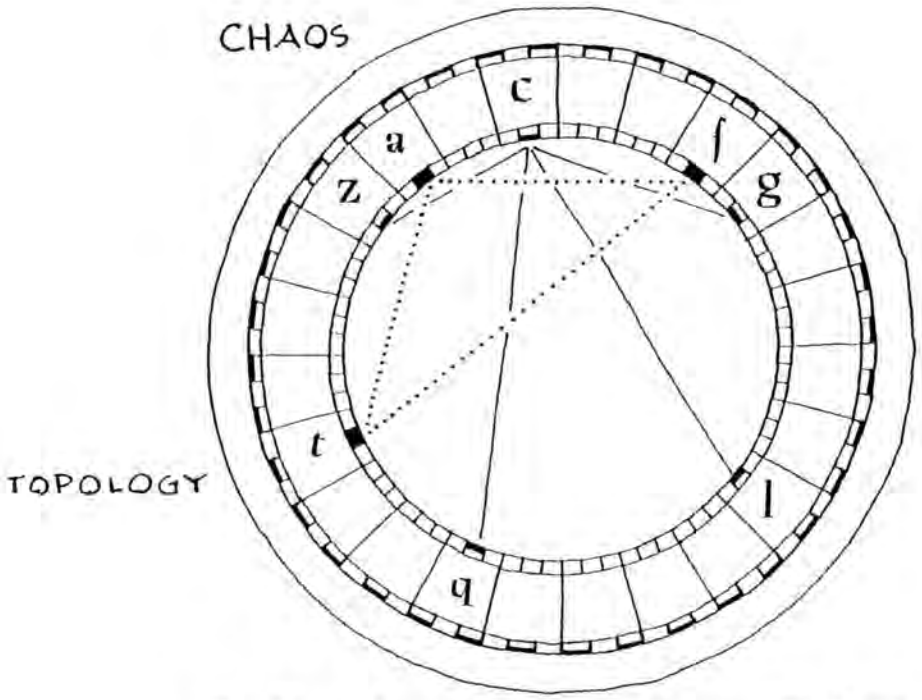

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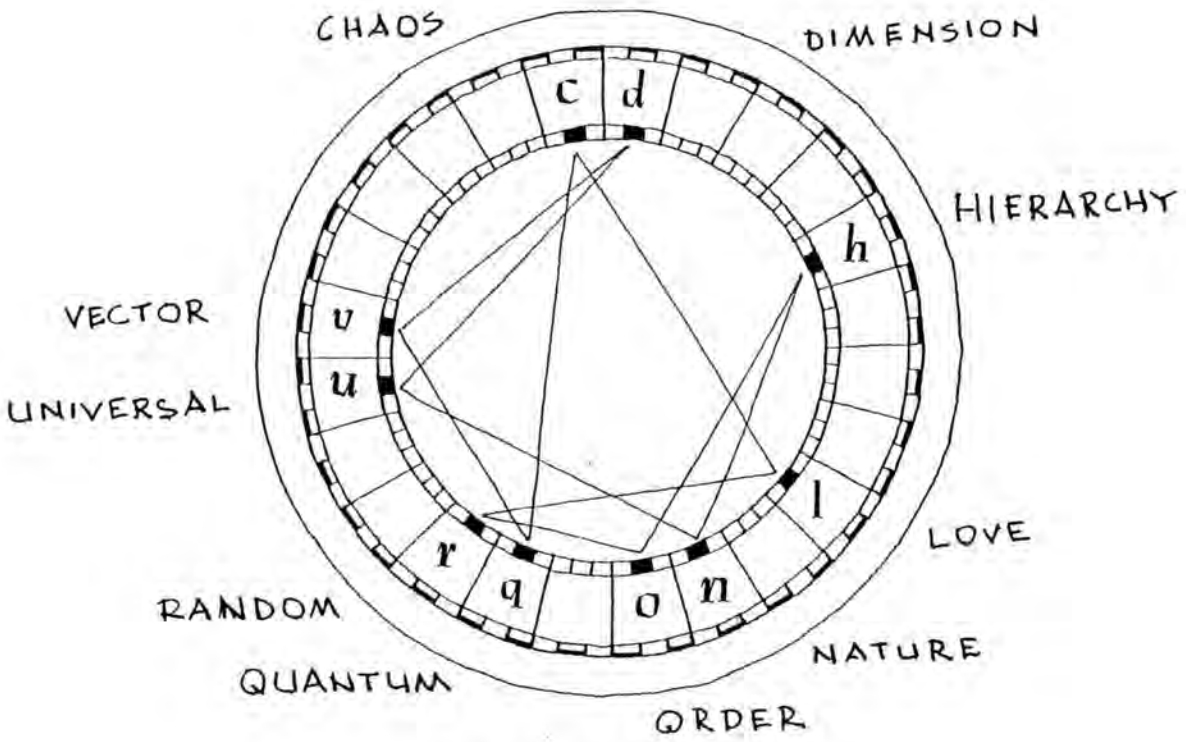

PATH

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